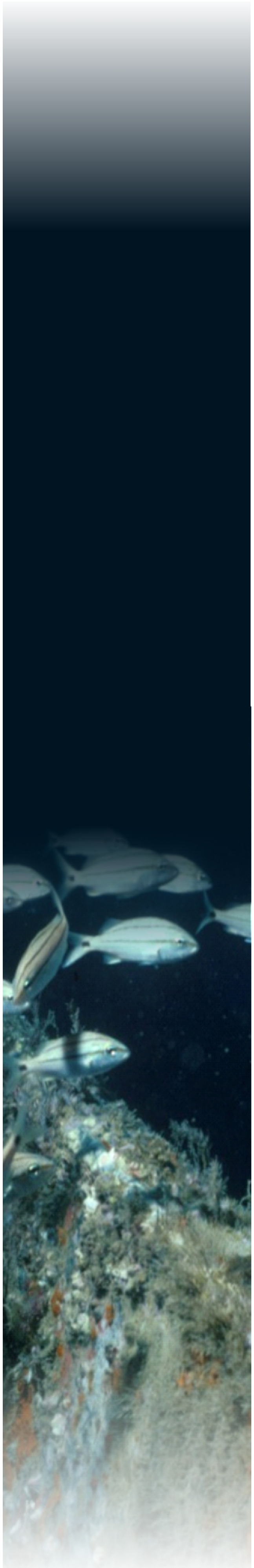
Artificial Reefing

Time Dynamic Model (TDM) Documentation

May 2005 (Draft Final)

SPAWAR
Systems Center
San Diego

PROGRAM EXECUTIVE OFFICE SHIPS



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DEDICATION

This document is dedicated to Mark Goodrich
(4/25/1957-1/7/2005)
for his outstanding contributions and total commitment to the Navy in the development of PRAM

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List of Abbreviations, Acronyms, and Terms

ATSDR	Agency for Toxic Substances and Disease Registry
CFR	Code of Federal Regulations
CTE	Central Tendency Exposure
DOC	Dissolved Organic Content
ECMRD	Escambia County Marine Resources Division
FI	Fish Ingested
F_{oc}	Fractional Organic Carbon
HEAST	Health Effects Assessment Summary Table
IR	Ingestion Rate
IRIS	Integrated Risk Information System
K_{oc}	Water-organic Carbon partitioning coefficient
Km	Kilometers
L	L
LOD	Limits of Detection
m	Meters
mg	milligram
NAVSEA	Naval Sea Systems Command
NCCOSC	Naval Command, Control and Ocean Surveillance Center
NEHC	Navy Environmental Health Center
ng	Nanogram
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OPPT	Office of Pollution Prevention and Toxics
PCB	Polychlorinated Biphenyl
PPM	Part per Million
PRAM	Prospective Risk Assessment Model
RAGS	Risk Assessment Guidance for Superfund
RfD	Reference Dose
RME	Reasonable Maximum Exposure
R_o	Resident Sediment Concentration
SCEM	Site Conceptual Exposure Model
SHHRA	Supplemental Human Health Risk Assessment
SINKEX	Deep-water Sinking Exercise
SPAWAR	Space and Naval Warfare
SPAWARSYSCEN	Space and Naval Warfare System Center
SSC-SD	SPAWARSYSCEN – San Diego
TDM	Time Dynamic Model
TL	Tropic Level
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TWG	Technical Working Group
UCL	Upper Confidence limit
USEPA	U. S. Environmental Protection Agency
ZOI	Zone of Influence

1.1 INTRODUCTION

The Naval Sea Systems Command (NAVSEA), manager of the reserve (inactive) fleet for the U.S. Navy, has prepared a decommissioned Essex class aircraft carrier, the ex-ORISKANY, for sinking, in anticipation of the vessel being deployed as an artificial reef in shallow marine waters off the western coast of Florida. Given that some solid Polychlorinated Biphenyl (PCB)containing materials, such as paints, bulkhead insulation, rubber products, and electrical cable insulation will remain onboard the vessel, the potential exists for PCB releases from these materials to the environment once the vessel has been sunk.

This document describes the Time Dynamic Model (TDM), developed by the Space and Naval Warfare (SPAWAR) Systems Center – San Diego (SSC-SD), that is used to predict abiotic media concentrations in the marine environment that may result from transient polychlorinated biphenyl (PCB) releases from the ex-ORISKANY vessel when it is initially deployed as an artificial reef. The model inputs and outputs are presented and described, and the temporal and spatial results are presented and discussed. This document also describes the coupling between the TDM and the biouptake and bioaccumulation algorithms from the Prospective Risk Assessment Model (PRAM Version 1.4, NEHC 2005), developed by the Navy Environmental Health Center (NEHC), Portsmouth, VA, to predict PCB concentrations in a range of biological organisms that are expected to reside on or near the artificial reef. Lastly, the approaches that will be used to evaluate the potential human health and ecological risks associated with a transient PCB release period at the ex-ORISKANY are described.

1.2 BACKGROUND

In July, 2004 the Navy submitted a draft Supplemental Human Health Risk Assessment (SHHRA) for the proposed ex-ORISKANY artificial reef to the U.S. Environmental Protection Agency (USEPA) Office of Pollution Prevention and Toxics (OPPT) to seek risk-based disposal of PCBs under the regulatory provision of 40 Code of Federal Regulations (CFR) 761.62(c) (NEHC, 2004). The USEPA invited the State of Florida to comment on the SHHRA. The SHHRA quantitatively evaluated the potential human health risks (cancer risks and non-cancer hazards) that would be associated with chronic human exposure to PCBs via a fish ingestion pathway. The risk assessment relied heavily on the results of the Prospective Risk Assessment Model (PRAM Version 1.3, NEHC 2004), a multimedia environmental model developed by the NEHC. The PRAM models release of PCBs from a sunken vessel, distribution of released PCBs into abiotic media compartments in the marine environment surrounding the vessel, uptake and bioaccumulation of PCBs into representative biota living on or near the reef, and potential human health risks associated with chronically ingesting fish caught at the artificial reef.

The USEPA and Florida reviewed the draft SHHRA document in July and August, 2004 and USEPA conducted an in-depth review of the PRAM (Version 1.3). Reviewers submitted written comments and recommendations to the Navy on both the SHHRA document and PRAM, then clarified their questions, concerns, and recommendations in Technical Working Group (TWG) teleconferences between August 2004 and January 2005, and in TWG[1] meetings with the Navy held in August, September, and November, 2004 (USEPA and Florida, 2004).

A major concern during the review was that the risk assessment evaluated the potential human health risks associated with lifetime, chronic exposure (risks associated with lifetime ingestion of fish that are caught on the artificial reef), but did not evaluate potential acute or subchronic health risks for the period 0 to 2 years after the sinking of the ex-ORISKANY (USEPA and Florida, 2004). USEPA and Florida reviewers suggested that, even though the potential long-term risks associated with chronic ingestion of reef fish may be considered the most significant to be evaluated, it was also important to evaluate short-term risks that might be associated with the "transient PCB release period" which occurs when the ship is initially sunk, and lasts up to two years following the deployment of the vessel as an artificial reef. During this transient release period, PCB release rates are variable and non-monotonic.

One problem arising from this recommendation was that PRAM was developed to estimate steady-state abiotic PCB concentrations, attained two years after vessel sinking. PRAM is a fugacity-based model, with a requisite assumption that a thermodynamic steady-state condition has been achieved, to solve for the distribution of PCBs within the abiotic and biotic media associated with the reef. The PRAM Volume 1.4 Documentation explains the model in more detail, and discusses the requirement (premise) of a thermodynamic steady-state condition assumption (NEHC/SSC-SD, 2005). The document also explains why a two-year point after deployment is a reasonable timeframe to achieve the thermodynamic steady state assumption for the PRAM, as summarized below.

1) An object deployed on the sea floor does not mature into a reef instantaneously; rather, it matures into a viable reef over a period of months or years. Reef colonization rates are not predictable, and are dependent on the reef's location, depth, prevailing water temperatures and currents, availability of colonizing species, and other factors. Based on a review of published literature, it seems reasonable to assume that a period of one to two years will be required to establish a mature, viable reef.

[1] The Technical Working Group is comprised of representatives from the USEPA (Office of Pollution Prevention and Toxics, Office of Water, and Region 4) , the State of Florida (Florida Fish and Wildlife Conservation Commission, the Escambia County Marine Resources Division, and other agencies), and the Navy and its subcontractors.

2) In order to model PCB accumulation and transfers into and out of significant biotic compartments, all of the biota significant to the reef food chain need to be present in the reef environment assumed in the PRAM; i.e., the reef must be a mature, viable reef.

3) Results from the PCB leach rate studies conducted by the Navy (SSC-SD, 2004) indicate that PCB leach rates from PCB-containing bulk product materials are PCB homolog-specific and material-specific.[2] The SSC-SD studies indicate that PCB homolog-specific and material-specific leach rates are initially unstable and increasing, then reach a maximum, after which they stabilize to a lower (as compared with initial leach rates), asymptotically decreasing rate within weeks, months, or in more than a year's time. In all cases, a lower asymptotic release rate, the "stable" release rate (as determined from regression analyses) was achieved prior to two years' time.

4) Considering both the timeframe needed for PCB release rates to reach stability (several weeks to more than a year), and the timeframe needed for a mature, viable reef to be established (one to two years after deployment), two years after deployment seemed a reasonable time to assume for steady-state conditions to be achieved in the near-reef marine environment.

The reviewers' concern with this two-year "lag time," to achieve conditions needed for PRAM (steady state) modeling, was that PRAM did not address conditions that might exist during the initial two year period from when the vessel is first deployed as an artificial reef. Since SSC-SD leach rate studies indicated that PCB homolog leach rates are initially relatively higher (as compared to the lower rates achieved over time), the concern was that there might be higher PCB levels in the abiotic marine environment near the vessel during the initial two year period after deployment relative to steady-state concentrations. Ensuing corollary questions arose: Might not higher PCB concentrations in abiotic media, albeit transient, lead to higher PCBs concentrations in biota residing on or near the reef during this period? Could there be higher, and/or unacceptable human health or ecological risks during this initial release period? Reviewers noted the lack of characterization of the potential PCB concentrations in abiotic media and in biota and lack of evaluation of the potential human health and ecological risks represented an uncertainty in the SHHRA.

In response, the Navy presented a possible solution to address the transient PCB release period at the ex-ORISKANY reef. It was noted that SSC-SD (formerly the Naval Command, Control, and Ocean Surveillance Center [NCCOSC]) had developed a model, in the context of the Navy's deep-water sinking exercise (SINKEX) program, which predicted released PCB concentrations

[2] The PCB leach rate studies conducted by Dr. Rob George et.al., SSC-SD (2004), are described in later sections of this document.

in abiotic media in a marine environment. In that early model, parameters such as diffusion and water current facilitated the distribution of PCBs within the ship and in the adjacent marine environment (NCCOSC, 1994). During a September, 2004 TWG meeting, it was suggested that the model (which is now named the TDM) could predict abiotic PCB concentrations as a function of both elapsed time and distance from when and where the vessel is sunk. It was also hypothesized that the resultant media concentrations could be used as inputs to PRAM's biouptake and bioaccumulation algorithms to derive biota-specific tissue PCB levels that would be associated those intervals. The biotic concentrations could then be used to evaluate ecological risks associated with the transient PCB release period. Once these biotic concentrations were found, they could also be used as inputs to the PRAM's human health risk equations to evaluate sub-chronic risks and hazards of fish ingestion.

Between September and December, 2004 a number of teleconferences were held between USEPA, Florida, and the Navy, to discuss the time-distance modeling approach, and application of TDM outputs as inputs to PRAM's algorithms to evaluate biotic uptake and bioaccumulation and potential human health and ecological risks during the first two years. In other sections of this document we describe the TDM, discuss how the TDM outputs will be matched up with the PRAM's biotic-food web and risk characterization algorithms, the approaches to evaluate potential human health and ecological risks associated with the "transient PCB release period" at the ex-ORISKANY reef.

1.3 PURPOSE OF USING MULTIMEDIA ENVIRONMENTAL MODELS

Human health and ecological risk assessments will be conducted to provide information on the potential human health and ecological risks using this vessel as an artificial reef.

The need to assess the potential human health and ecological risks before the vessel is sunk presents an obvious problem: there is no "potentially contaminated reef site" to investigate. Eventually, the ex-ORISKANY and a variety of biological organisms will form the reef, after the vessel has been sunk and enough time has elapsed for significant colonization to have taken place. Before then, we must model how anticipated PCB releases from a sunken vessel might distribute within the receiving and developing ecosystem. The TDM, coupled with PRAM, could serve as a multimedia environmental model to predict the PCB concentrations that are likely to result in abiotic and biotic media within the marine environment at specific distance intervals from the sunken vessel and at specific periods of time soon after the vessel has been deployed as an artificial reef.

The TDM and PRAM are based on scientifically sound and widely accepted physical and biological algorithms and model constructs. They have been constructed to simulate the marine environment and physical conditions that are expected at the ex-ORISKANY reef site, pursuant to such sound scientific principles and within the limits imposed by underlying modeling assumptions. Although there are uncertainties associated with both models (model assumptions and uncertainties are described elsewhere in this document), enough conservatism has been built into the modeling framework that we are confident that the outputs of these models would not under-predict the PCB concentrations that are likely to result in abiotic and biotic media in the marine environment associated with the ex-ORISKANY artificial reef. Therefore, the model results can be used as a risk management tool to evaluate the potential human health and ecological risks associated with the ex-ORISKANY reef to support 40 CFR 761.62 (c) disposal approval decisions about beneficial use of decommissioned vessels to create artificial reefs**.** Figure 1-1 presents a block diagram depicting the relationship between TDM and PRAM, and how inputs and outputs from both models are used.

The ex-ORISKANY vessel is a Essex-class aircraft carrier. It is 888 feet (271 meters (m)) long, and has an average beam (width) of 90 feet (27 m) (NEHC, July 2004) and is approximately 90 feet high to the flight deck, with another portion, the "island" extending up approximately another 45 feet (14 m). An estimated 500 kilograms of PCBs will remain onboard the ex-ORISKANY after the vessel has been prepared for sinking.[3] PCBs are present in bulk materials, such as bulkhead insulation, rubber products, and wire insulation, found throughout the vessel. When the vessel is sunk as an artificial reef, laboratory observations (SSC-SD, 2004) indicate these materials will slowly release PCBs into the water by leaching.[4] There is a concern that the released PCBs would be further distributed in other environmental media, including biota (NEHC, 2004).

The TDM, described below, was developed to predict the fate of PCB homologs released in the first two years after the vessel is sunk. The conceptual approach of the model is first presented, then mapped to specific lines of model code. The computer code for the model is provided in Appendix A. Graphs of modeled PCB homolog concentrations throughout the model domain are provided in Appendix B. PCB homolog concentrations adjacent to and inside the ship and mass budgets are provided in Appendix C.

2.1 GENERAL DESCRIPTION OF THE TIME DYNAMIC MODEL (TDM)

The model predicts the transport and abiotic fate of specific PCB homologs, due to their distinct chemical characteristics. PCB homologs are first released into water internal to the ship, based on Navy leach rate studies (SSC-SD, 2004)[4]. PCBs approach equilibrium concentrations with dissolved organic carbon (DOC) and total suspended solids (TSS) within the ship over a period averaging about four hours (see Section 2.1.2). PCBs then slowly leak outside of the ship, and are advected away in the prevailing current. The water body around the sunken vessel (water column) is presumed to be divided vertically by a pycnocline – a density stratification that slows exchange of water above and below it. Outside the ship, PCBs approach new equilibrium concentrations in water, DOC, TSS above and below the pycnocline, and sediment to a distance of 3000 m in all directions from the ship. These abiotic media or compartments are termed

[3] This estimate is based on the material sampling results (indicating the concentrations of PCBs in specific PCB-containing bulk product materials on the ex-ORISKANY) and estimates of the amount of PCB-containing bulk product materials that remain on the ex-ORISKANY after vessel preparations. The source term estimate report (CACI, 2004), presented in Appendix D, provides this information.

[4] A two-year laboratory study undertaken by the Navy has estimated the release rates of PCB homologs from the shipboard materials, projecting that these release rates will approach steady-state conditions beyond the two-year measurement period (SSC-SD, 2004). A description of the PCB leach rate study is provided in Section 2.3 of this document.

matrices. Predicted concentrations in the abiotic media subsequently provide input to the biotic-food web module (food chain algorithms) in PRAM.[5]

2.1.1 Model Construction and Assumptions

The ex-ORISKANY is modeled as an elliptical volume 270 m by 36.5 m and 6.9 m high, sunk in 64 m of water. The dimensions were chosen to match the estimated volume of the real ship as well as the geometry used in the PRAM (NEHC/SSC-SD, 2005). A pycnocline is fixed at 15 m, based on local diver experience (Turpin, 2004). PCBs are released within this ship volume at 1 minute intervals and mix instantaneously into the interior water. PCBs adsorb to DOC and TSS inside the ship. Figure 2-1a shows the ship dimensions in plane view. Figures 2-1b and 2-1c are estimated path lengths of DOC and TSS inside the vessel, based on random transects. A slow, internal current of 0.25 cm sec^{-1} (approximately equal to 0.005 knot/hr, and based on the assumption that the flow rate is equivalent to 1/100 of the current flow rate [25 cm sec^{-1}] external to the vessel) releases water, DOC and TSS from inside to outside of the ship. The most likely DOC and TSS path length of approximately 37 m results in an expected residence time of 247 minutes within the ship. Figure 2-1d shows the modeled first order kinetics of PCB adsorption and desorption between water, DOC, TSS and sediment. Ninety-nine percent of equilibrium concentrations are assumed reached within 24 hours (Di Toro and Horzempa, 1982). These kinetics specify that 54.7 % equilibrium is reached between water, DOC and TSS during the 247 minute residence time within the ship.

Outside of the ship, PCB concentrations are calculated in concentric bins (elliptical annuli) 15 m wide, expanding away from the ship and extending to the surface. A width of 15 m was chosen to match the distance a 25 cm sec^{-1} (0.5 knot/hr) current travels in the 1 minute model time step. The bins are vertically divided at the pycnocline, the upper bin being 15 m tall and the lower bin 49 m tall. The model extends outwards 200 bins (3000 m) from the ship. The model assumes advective plug flow; the entire volume of a bin (water, suspended solids and dissolved organics) is moved to the next bin each time step. Sediment is not transported between bins.

The 1 minute time step allows 0.32% equilibrium concentrations to be reached between water DOC and TSS and sediment below the pycnocline (Fig 2-1d). Approach to equilibrium between water DOC and TSS above the pycnocline is much slower and governed by vertical turbulent diffusion. An eddy diffusivity K_z of 0.1 cm^2 sec^{-1} was assumed to mix dissolved PCBs across the pycnocline (Toole et al, 1994; Law et al, 2003). Figure 2-2a plots the approach to equal PCB water concentrations above and below the pycnocline with a K_z=0.1 over time. Nintynine percent equal concentrations (99% equilibrium) is reached in 64.7 days. This period is the same in every

[5] The PRAM biotic-food web module employs bioconcentration factor (BCF) and bioaccumulation factor (BAF) algorithms, as described in V 1.4 PRAM Documentation (NEHC/SSC-SD, 2005).

model bin, regardless of size, because the area across the pycnocline grows at the same rate as the bin volume, which is essentially cylindrical. Figure 2-2b plots time to 99% equilibrium as a function of $K_{z.}$ A larger K_z value denotes more energetic vertical mixing and shorter time to equilibrium. When K_z=0.1, a 1 minute time step allows time for only 0.0011% of equilibrium PCB concentrations between water, DOC and TSS above the pycnocline to be reached.

Several assumptions, derived from the PRAM food chain model, are made about the matrices in which PCB homolog concentrations are calculated. Water is assumed to have a density of 1 g ml^{-1}. Sediment is assumed to contain 1% total organic carbon (TOC), denoted in the model as fraction of organic carbon, f_{oc}; in the case of sediment equal to 0.01. Sediment and adsorbed PCBs are assumed mixed by infaunal organisms (bioturbated) to a depth of 10 cm. Sediment is assumed to have a density of 1.5 g ml^{-1}. DOC is assumed to occur at 0.6 mg $liter^{-1}$ in the water column and be composed of 100% TOC. TSS is assumed to occur at 10 mg $liter^{-1}$ and be composed of 15% TOC. The ship is assumed to have no internal structure or adsorptive sediment. Transfer or loss by evaporation at the water's surface is not modeled, nor are PCBs modeled as occurring in the water column directly above the ship.

Equilibrium homolog concentrations are defined as homolog water concentration times the bulk partition coefficient of the matrix (Fetter, 1999; Maidment, 1993). The bulk partition coefficient is the product of the water-organic carbon partitioning coefficient K_{oc} and the fraction organic carbon f_{oc}. K_{oc} values specific for each homolog were taken from PRAM and listed in Table 2-1. The bulk partition coefficient is also the slope of the initial sediment adsorption isotherm (Weber et al., 1990; Thibodeaux, 1996) Desorption of PCBs from sediment is assumed to follow a shallower isotherm than adsorption and preserve a residual adsorbed fraction which cannot be reversibly desorbed (Di Toro and Horzempa, 1982).

In the model, PCBs are released only down-current from the ship, but the currents flow equally in all directions over time. As a result, PCB dispersal is assumed to be radially symmetric around the ship; the PCB load is distributed in all directions in each one minute time step. If subsequent data suggest that currents and PCB dispersal are limited to particular directions, the model can be rerun with proportionally higher initial water concentrations, due to the smaller dispersal bin volumes. Within each minute time step, water, DOC, TSS and sediment can either adsorb or desorb PCBs, depending on their current concentration and their equilibrium concentration. Plug flow moves water and entrained DOC and TSS into the next outer bin in each time step.

In the second and subsequent bins, water PCB concentrations are diluted by the larger volume of the next bin. The density of DOC and TSS in the water column (g ml^{-1} water) is assumed to be constant; hence there is more DOC and TSS in the next, larger, outer bin than in the bin before it. In order to conserve PCB mass associated with DOC and TSS moving from an inner bin to the next outer bin, potential adsorption or desorption is calculated for only the DOC and TSS advected from the previous inner bin into the current bin. The current bin contains DOC and TSS advected into it from the previous bin, plus additional DOC and TSS to maintain the same density. The new PCB mass adsorbed to DOC or TSS from the previous bin is divided by the mass of all the DOC or TSS in the current bin – effectively diluting it. This approach makes sense if one assumes that currents first advect particles in one direction, then another, making the average concentration equal to the incoming load averaged over all DOC or TSS mass at that range from the ship.

2.1.2 Model Issues

There are three model issues that should be highlighted. The first is that DOC and TSS inside the ship are assumed to immediately reach their 247 minute, 54.7% approach to equilibrium PCB concentrations, regardless of how long the DOC and TSS were actually in the ship. This simplification eliminates the need to keep track of specific particle residence times, in keeping with the assumption of no internal ship structure. It has the effect of increasing the PCB load in these media and reducing it in water inside the ship.

The second issue is that PCB flux across the pycnocline via turbulent mixing of water, DOC and TSS is handled implicitly by slowing the approach to equilibrium over 64.7 days. Rather than having fractional mixing occur across the pycnocline within the 1 minute time step and then allowing adsorption and desorption to occur above the pycnocline, TDM simply slows down the approach to equilibrium above the pycnocline. This simplification is justified since the K_z term dominates the apparent rate of adsorption of upper water matrices compared to the adsorption kinetics, and because calculated PCB flux across the pycnocline is always upward into those media (see figures in Appendix B). Allowing K_z to control adsorption above the pycnocline however forces a small slowing in PCB flux rates, predicted from 24 hour kinetics, from matrices that release PCBs below the pycnocline. For example, predicted net PCB mass flux out of water, DOC and TSS into the sediment and into media above the pycnocline exceeds the net adsorptive capacity of those media to absorb it within the 1 minute time step. In this case, the PCB flux from the water is reduced to accommodate the adsorptive kinetics of those receiving media.

The third issue is that PCB desorption from DOC and TSS do not follow the same isotherm as used for sediment. The shallower desorption isotherm was not implemented for DOC and TSS for computational simplicity, though Di Toro and Horzempas (1982) analyzed PCB adsorption from, and desorption to, suspended sediments. PCB concentrations in water-borne DOC and TSS below the pycnocline are maximum adjacent to the ship, then decrease two orders of magnitude, well below the residual sediment concentration R_o (equal to 0.57*maximum concentration).

The apparent drop in concentration is due primarily to volume dilution, however, as DOC and TSS from the ship move into larger bins containing DOC and TSS with no PCB load. Volume from within the ship to the outermost bin below the pycnocline increases 183 fold, accounting for the apparent decrease in concentration. As a result, the net flux of PCBs out of DOC and TSS is reduced.

Calculation of net loss of PCB homologs from TSS and DOC during their advection from the ship to the model's perimeter at 3000 m, showed that more than 43% of the PCB mass was desorbed was only three instances, and always in the last (farthest) bin. These were for hexachlorobiphenyl on day 1 (43.6% lost), for nonachlorobiphenyl on day 83 (45.1% lost), and decachlorobiphenyl on day 83 (45.4% lost). Again, these small losses are not due to implementing the shallower isotherm and R_o resistant fraction, but rather the lowering of concentration (and desorption) by dilution and the short 200 minute residence time of these matrices in the model.

The net affect of this simplification is that DOC and TSS release their PCB load into other matrices farther from the ship. This is more important for the more-chlorinated homologs, for which DOC and TSS are important PCB transport vehicles from the ship (see relative mass in these matrices within the ship, Appendix C). If model currents were slower and residence times longer, Di Toro and Horzempas (1982) desorption constraints probably should be implemented. Above the pycnocline, DOC and TSS always increase in PCB concentration as they are advected away from the ship, so desorption isotherms are not an issue (Appendix B).

2.1.3 Model Algorithms

The model comprises of two calculation loops enclosing the adsorption and desorption code. The outer loop is a time loop that steps the model through the measured homolog release sequence over two years, one minute at a time. The inner loop calculates concentrations in a series of bins as concentric annuli around the ship. The inner spatial bins loop is broken into three parts: inside the sunken ship, the first bin adjacent to the ship, and all other concentric bins. Each bin is subsequently divided into a lower bin below the pycnocline and an upper bin above it.

The model assumes that PCBs released inside the ship dissolve instantaneously into the water occupying the entire ship volume. The following steps occur in the ship and each bin: (1) the total PCB mass is summed, (2) equilibrium concentrations in the various media are calculated, based on bulk partitioning coefficient, i.e., the K_{oc} of each homolog and f_{oc} of the media, and (3) the fraction of the mass flux necessary to reach equilibria is allowed, commensurate with the 247 minute residence time in the ship or the 1 minute residence time in each bin. The mass flux is calculated as the concentration change necessary for equilibrium times the mass of the particular media in the ship or bin.

The following algorithms calculate fluxes and new concentrations:

1. Total PCB mass in the bin is first determined as follows:

PCB Total = mass in water + mass in DOC + mass in TSS + mass in sediment

2a. Equilibrium mass distribution in the bin is determined as follows:

PCB Total in equilibrium = equilibrium water concentration*water mass

+ equilibrium DOC concentration* DOC mass

+ equilibrium TSS concentration*TSS mass

+ equilibrium sediment concentration*sediment mass

The equilibrium concentration in DOC , TSS and sediment is simply the water equilibrium concentration*K_{oc}*$f_{oc,}$ for each matrix. The above equilibrium distribution can be rewritten:

PCB Total equilibrium = equilibrium water concentration*water mass

+ equilibrium water concentration *K_{oc}*f_{oc} * DOC mass

+ equilibrium water concentration *K_{oc}*f_{oc} *TSS mass

+ equilibrium water concentration *K_{oc}*f_{oc} *sediment mass

which can be expanded to include media above and below the pycnocline and solved first for water equilibrium concentration:

Water equilibrium concentration = PCB Total/[(upper water mass+lower water mass)

+ (upper TSS mass+lower TSS mass)*K_{oc}*0.15

+ (upper DOC mass+lower DOC mass)*K_{oc}*1.0

+ (sediment mass)*K_{oc}*0.01)]

The sediment equilibrium concentration:

Sediment equilibrium concentration = water equilibrium concentration*K_{oc}*0.01

and the equilibrium of the other matrices have the same form.

2b. If sediment concentrations are below their maximum values, the irreversibly adsorbed PCB fraction bound to the sediment, as argued by Di Toro and Horzempa (1982), must be taken into account. This affects the water and sediment equilibrium concentrations slightly:

Water equilibrium concentration = (PCB Total - R_0*sediment mass)/

[(upper water mass+lower water mass)

+ (upper TSS mass+lower TSS mass)*K_{oc}*0.15

+ (upper DOC mass+lower DOC mass)*K_{oc}*1.0

+ (sediment mass)*K_{oc}*0.01)]

the sediment equilibrium concentration is now:

Sediment equilibrium concentration = R_0 + (water equilibrium concentration*0.43* K_{oc}*0.01)

where R_0=0.57, and 0.43 reduces the original slope of the adsorption isotherm. Equilibrium concentrations in DOC and TSS are unchanged.

3. The flux per minute (or 247 minutes in the ship) is some fraction of that necessary to reach equilibrium, determined by the kinetics of adsorption/desorption and vertical mixing. For example:

Water flux = fraction*(equilibrium water concentration - real water concentration)*water mass

The flux can be either positive or negative. Water flux is almost always negative for water. The fraction term, discussed above, is 0.547 for 247 minutes in the ship, 0.0032 for matrices below the pycnocline, and 0.0000107 for matrices above the pycnocline. After the flux is calculated, a new PCB mass and concentration in each matrix is calculated.

Finally, to achieve mass balance, the summed PCB mass leaving the water and desorbing from any medium must be limited by the ability of the other media to adsorb it. Since the media above the pycnocline are limited in uptake by vertical mixing rather than adsorption kinetics, the calculated 1 minute desorption from media below the pycnocline provide too much PCB and their release must be curtailed. This adsorption "brake" is calculated for each bin. Concentrations of PCB homologs in all matrices are calculated as mass to mass; thus, a water concentration of 10^{-12} is 10^{-12} g PCB per g or ml of seawater.

2.1.4 PCB Homolog Mass Budgets

A PCB homolog budget calculation was made to test whether mass was conserved in the model. Two mass conservation algorithms were used. The first calculated the difference between the mass of each homolog released from the vessel and each homolog mass retained in the model domain among the different media. The second algorithm summed each homolog mass leaving the model domain via advection of water, DOC and TSS.

The difference and sum converged within 24 hours after equilibrium sediment PCB concentrations were reached for all homologs except decachlorobiphenyl. The difference and sum remained less than homolog mass released, but approached the released mass as the percent retained in the model domain became insignificant.

Graphs of the predicted homolog concentrations and mass in the matrices over time are provided in Appendix C. (Figures C-1 to C-20). A spreadsheet indicating the homolog-specific release values that were input to the model is also provided in Appendix C.

2.1.5 Code Description

The computer code for the TDM model is written in C programming language. The below descriptions provide a guide to the approach used in the TDM program code, which is presented in Appendix A.

Initial setup:

- "Set c:\pcb\simul\finalprephomologs," at line 2, is input from the SSC-SD (SSC-SD, 2004) PCB homolog release rate study. The "finalprephomolog" file contains expected leach rates after 72.6% of the PCB-laden material has been removed. This data file is 11 columns by 18 rows. The 11 columns are the daily release rates for each of the 10 PCB homologs and an additional column listing the time for which a particular release rate was measured (see section 2.2 and last figure in Appendix C).

- Lines 4 to 51 set up the arrays for temporary storage. Lines 55 - 127 initialize variables and calculate the ship and bin volumes and masses of the various matrices. Lines 58-59 set the fraction of equilibrium reached per minute for adsorption kinetics and vertical mixing. Line 60 sets the fraction of adsorptive equilibrium reached over the expected 247 minute residence time in the ship. Addition of a ship interior was made late in writing the code. The indexed variables pertain to bins outside the ship. Non-indexed variables are water, DOC and TSS mass inside the ship. Volumes are multiplied by density to convert to mass for concentration calculations.

- The homolog identification, period of release in minutes, K_{oc}, and bulk partition coefficients are set up in lines 130-138. This particular run models the dispersal of pentachlorobiphenyl (Cl5 in line 130).

- The outer time loop starts at line 141. The "start" flag keeps PCBs from leaking into adjacent bins until the PCB contaminated water actually advects to the bin. It is used when calculating PCB concentrations in the second and subsequent bins. The inner spatial bin loop starts on line 206.

Inside the ship:

- Internal ship calculations start at line 150. The total PCB mass calculation is made at line 156. Water, TSS and DOC equilibrium calculations are made on lines 158-160. These are the only abiotic matrices assumed in the ship. The flux rate permissible in 247 minutes is calculated in lines 162-164. A potential brake on PCBs leaving the water is calculated in lines 166-174. Its use hinges on the value of the net flux calculated in line 166. If the net flux is negative, the brake is employed. The opposite case, where net flux is positive – meaning that adsorption out-stripped desorption – was never observed but a corresponding brake is made ready in lines 176-181. The new mass distributions and concentrations after flux are calculated in lines 183-190.

The first bin external to the ship:

- Calculations in the first and concentric bins follow the same pattern as above, except that the full complement of matrices is addressed. The spatial bins (concentric annuli) loop starts at line 206 and ends at line 411. The PCB mass input into the bin is only from water, DOC and TSS from the ship (lines 214-221). The initial mass above the pycnocline is zero (lines 209-211).

- The total PCB mass to be reallocated in 1 minute is calculated in line 233.

- Calculation of equilibrium matrices concentrations begins at line 235 where the residual sediment concentration R_0 reduced isotherm px are calculated. Then, depending on whether the sediment concentration is at its previous all time high (line 241) or is less (line 246), equilibrium concentrations are calculated in lines 241-255.

- The allowable flux is calculated (lines 259-265), net flux is checked if negative (line 267) and negative flux rates are braked if necessary (lines 272-281). If net flux is positive, the brake is applied to adsorbing matrices (lines 283-292). Finally the new masses and concentrations in the seven matrices are calculated (lines 294-314) and the maximum sediment concentration for the first bin is updated if necessary (line 299).

All the other bins:

- Calculations follow almost identically to those above. The new mass imported from the previous bin by advective flow is calculated in lines 323-328. The 'start' flag is employed to determine whether it is reasonable that the PCB-laden water has reached the bin, in order to prevent numerical dispersion between bins. The new mass is added in line 333, and equilibrium calculations are made in lines 337-351. Allowable fluxes are calculated in lines 355-361. A brake on desorption or adsorption is applied in lines 363-387, depending on the sign of the net flux. New matrix PCB masses and concentrations are calculated in lines 389-409.

Budgets and graphics

- The PCB homolog budget sums and differences are calculated at lines 415-449 and are fairly self-explanatory. "Cumloss1" predicts PCB export out of the model as the difference between what PCB mass was released and what resides in model matrices. "Cumloss2" is accumulated PCB mass exported out of the model, dissolved in water and adsorbed to DOC and TSS. The end of the time loop is at line 450.
- The remaining code exports predictions for graphics and subsequent PRAM food chain model use and does not impact PCB predictions (see section 2.3).

2.2 INPUTS TO THE TDM

The TDM uses empirical data that were derived from three significant sources:

- The December 7, 2004 CACI report, "Final Report, Revision 4, Polychlorinated biphenyls (PCB) Source Term Estimates for ex-ORISKANY (CVA34)" (Appendix D)
- The October, 2004 SPAWARS Systems Center-San Diego (SSC-SD) report, "Draft Final Report: Investigation of Polychlorinated Biphenyl (PCB) Release-Rates from Selected Shipboard Solid Materials Under Laboratory-Simulated Shallow Ocean (Artificial Reef) Environments"
- The December, 2004 SPAWARS Systems Center-San Diego (SSC-SD) report, "Empirical PCB Release for ex-ORISKANY over Initial 2-year Timeframe - Dataset Development for Time Dynamic Model"

The data provided in each of these sources is briefly discussed below.

2.2.1 PCB Source Terms for the ex-ORISKANY (CACI, 2004)

The December 7, 2004 CACI report. This report provided information about the types and amounts of PCB-containing materials that were resident on the ex-ORISKANY before the vessel was prepared for sinking as an artificial reef, and estimates of the amounts of these PCB-containing materials that remained after two stages of removal actions had taken place (i.e., after 15 % of the bulkhead insulation (BHI) material had been removed, and after 72.6% of the BHI material had been removed). The amount of material remaining on the vessel after the final removal action is reported in terms of percentage reduction of initial amounts of material. The concentrations of PCBs found in each of the PCB-containing bulk products (upper 95% confidence levels) are also reported.

2.2.2 Derivation of PCB Release Rates from Shipboard Materials (SSC-SD, 2004)

The October, 2004 SSC-SD report was provided to the U.S. EPA, State of Florida, and the U.S. Navy as an electronic report and data files in October, 2004. This report provided information about how material-specific and PCB-homolog specific leach rates were derived, based on laboratory experiments. Briefly, samples of a variety of PCB-containing materials that were found on Navy vessels were submersed in a holding tank filled with constituted sea water, and held at constant temperature and pressure that simulated the sunken vessel environment. The liquid surrounding the materials was kept stirred, and at various time intervals, aliquots of the water were removed and analyzed for PCB homologs and for total PCBs (as the sum of homolog concentrations). Fresh sea water was then added to the holding container, and the material soaked in the sea water for the next time interval. From these experiments, material-specific and PCB homolog-specific leach rates were derived as discussed in the next section.

2.2.3 Derivation of Homolog-Specified and Total PCB Mass Rates from Shipboard Materials (SSC-SD, 2004)

Using information from the CACI PCB Source Term report, and the homolog-specific leach rates derived in the SSC-SD leach rate studies, the total masses of PCB-containing materials remaining onboard the ex-ORISKANY after removal actions were calculated and the mass of PCBs that were released from each material, per day, were calculated. The material-specific PCB mass releases are reported in units of nanograms of PCB per gram of material released per day (ng/g/day). These data were used in the TDM to model PCB distribution into the marine environment as a function of time and distance from the vessel.

2.3 TDM OUTPUTS

As described in earlier sections, the TDM time domain is from 0 to 730 days after the vessel is deployed as an artificial reef, and the TDM distance domain is from 0 to 3000 meters from the sunken vessel. The TDM was constructed to estimate PCB concentrations in abiotic matrices at one minute time intervals, over the entire time domain, and in 15 meter distance intervals, over the entire distance domain.

The TDM can be used to derive estimates of PCB homolog-specific concentrations, or the total PCB concentration in abiotic media for any of the time-distance bins. The TDM can also be used to track the mass release of any specific PCB homolog through the time-distance bins, and to track how much of the released mass remains in the model domain (i.e., is resident in the abiotic matrices within the model domain) and the mass that leaves the modeled domain, for example, as suspended solids and dissolved organic carbon resident in marine water exits the model domain because of the assumed water current.

2.3.1 Discussion of TDM Outputs (Spatial and Temporal Considerations)

Several TDM outputs are discussed in this section.

Description of three-dimensional plots of total PCB and PCB homolog concentrations are presented in Appendix B. Seventy figures are presented in this appendix. The figures are sets of total PCB and nine homolog (cl1-cl7, cl9, and cl0) concentrations in the seven abiotic matrices (upper water, lower water; TSS in upper water, TSS in lower water; DOC in upper water, DOC in lower water; and sediment). Octachlorobiphenyl release was not measured, and subsequently not modeled.

Data shown in the Appendix B figures are daily mean concentrations. The abiotic matrices are water, TSS and DOC above and below the pycnocline; and sediment. In each set of concentrations per matrix, the total PCB concentration is shown first to establish the color concentration scale. Concentration is shown on the vertical axis, while distance from the ship and time are shown in the horizontal axis. The same color scale is used on the nine subsequent homolog concentration plots per media, while the numerical scale accommodates the range of values for that homolog. This allows quick detection by color of the most significant homolog to total PCB loading in the matrix.

Comparison of matrix concentrations and mass inside and outside the ship by homolog are presented in Appendix C. This appendix provides 30 two-dimensional plots. The figures compare homolog and total PCB concentrations and mass in all the seven abiotic matrices, inside and outside of the ship over time. Concentration and mass values are daily means. Distance from the ship was fixed at the range where the total PCB and homolog concentrations were found to be maximum. For instance, below the pycnocline, water, TSS, DOC, and sediment concentrations were greatest in the first bin, 0-15 m from the ship. Above the pycnocline, water, TSS and DOC concentrations were highest in the last bin, 3000 m from the ship (see Appendix B). Inside the ship, there is only one range, since the ship was considered non-compartmentalized and well-mixed.

The last figure is the daily homolog release rates measured by Dr. Rob George and used as model input. The first 30 figures are divided into ten sets of three. The ten sets present data for each of the nine PCB homologs, plus total PCBs. No release of octachlorobiphenyl was measured and therefore it was not modeled in this study. The three figures per set show concentrations outside the ship, concentrations and mass inside the ship, and mass outside the ship. Concentration and mass inside the ship were not combined in the figures showing conditions outside the ship to maintain some clarity in the graphs.

A brief explanation of three figures per homolog is presented below. The first figure shows only concentrations outside the ship and all units are g PCB/ g matrix. Concentrations below the pycnocline are shown as solid lines, concentrations above are shown as dashed lines. The second figure shows concentration and mass in the ship in water, TSS and DOC. Sediment was not assumed to occur in the ship. Concentrations are shown as dashed lines; units in g PCB/g matrix. Mass is shown as solid lines; units in gram. Mass are plotted on the same vertical axis, so mass values are read as g PCB, not g PCB/g matrix. Total PCB mass inside the ship is shown also as a thick grey line. The third figure is the PCB mass outside of the ship. The upper red line is the total PCB released from the ship, the grey line is the total released minus the sum remaining in the model, and the black line is the total PCB leaving the model domain. The latter two plots were used as a check on model mass balance. The grey and black lines quickly converge and are offset from the red line by the PCB mass that remains in the model. The other solid lines represent PCB mass in matrices below the pycnocline, the dashed lines represent mass in matrices above the pycnocline.

2.3.2 Intended Use of TDM Outputs, for Human Health and Ecological Risk Assessments

As previously noted, the TDM time domain is from 0 to 730 days after ship sinking, and the TDM distance domain is from 0 to 3000 meters from the sunken vessel. Although the TDM was constructed to estimate PCB concentrations in abiotic matrices at one minute time intervals, over the entire time domain, and at 15 meter distance intervals, over the entire distance domain, for the human health and ecological risks assessments it was recognized that 24 hour time intervals would be the finest resolution needed for determining abiotic PCB concentrations, and that the distance intervals closest to the sunken vessel would be most significant for determining exposures to reef-associated organisms.

For these reasons, the TDM outputs provided for use in developing data for the human health and ecological risk assessments were for the specific distance intervals, 0 to 15, 0 to 45, and 0 to 60 meters away the sunken vessel, and for the following time-averaged intervals: daily (each 24-hour period, starting at day 1, through day 730); day 1 (24 hours), day 7 (the 6 days following day 1); day 14 (the 7 days following day 7); day 28 (the 14 days following day 14); 6 months (the 5 months following day 28); 1 year (the 6 months following day 180); and 2 years (the 1 year period following day 365). TDM outputs (time-averaged PCB concentrations) were provided for each PCB homolog (mono- through decachlorobiphenyl)[6], and for total PCBs (as the sum of PCB homolog concentrations) in each of the abiotic media compartments (water, suspended solids, and dissolved organic carbon in the upper and lower water columns, and in the internal vessel compartment; and in sediment). The 24-hour output data were calculated as the mean concentration of the 1-minute increment data for the preceding 24 hours. The distance outputs were calculated as the arithmetic mean concentrations for the relevant bins. For example, the 0 to 60 meter output data were calculated as the arithmetic mean values of the 0 to 15 meter, 15 to 30 meter, 30 to 45 meter, and 45 to 60 meter bins.

In addition to the above time intervals, for the human health risk assessment, the 2 year period following ship sinking was sub-categorized as an "acute" exposure period, 0 to 90 days following ship deployment, and a subsequent "subchronic" exposure period, from 91 to 730 days (i.e., the rest of the two year period). Graphs of the total PCB concentrations in abiotic matrices, indicating the difference in PCB concentrations over the 0-90 day period and the subsequent 91-730 period, are provided in Appendix G.

For use in the human health and ecological risk assessment, TDM outputs were provided as a series of Microsoft Excel ™ (Excel) files that provided time-averaged homolog-specific and total PCB concentrations in abiotic media at distance intervals of 0 to 15, 0 to 45 meters, and 0-60 meters away from the sunken vessel for all the time intervals described above.

2.4 MODEL UNCERTAINTIES

There are a number of sources of uncertainty in all environmental models. In the following paragraphs we discuss some of the significant sources of uncertainty associated with the PRAM and TDM that have not been previously discussed.

2.4.1 Vessel Geometry

We have used a simplified geometric shape to approximate the ex-ORISKANY's dimensions, as opposed to trying to derive a mathematical description that would account for the complex contours of this ex-aircraft carrier. The ex-ORISKANY has a length of 888 feet (270 m), an average beam (width) of 117 feet (36 m)[7], and is approximately 90 (~27 m) feet high up to the flight deck, with another portion, the "island," extending up approximately another 45 feet (14 m). The vessel has a displacement of 27,100 tons, and thus it is assumed that when it is deployed as an artificial reef, it will sink into the sediment to some depth. We have calculated an "effective ship height" of 6.9 m, which was used in conjunction with a length dimension of 271 m and an

[6] There are no octachlorobiphenyl (cl-8) outputs, since none of the PCB-containing materials on the ex-ORISKANY were found to contain octachlorobiphenyl homolog.

average width of 36 m, to approximate the dimensions of the vessel's displacement in the marine environment. It should be noted that the vessel is not an exact elliptical shape, and its geometry is complex. Therefore, the ZOI or boundary conditions are approximate.

2.4.2 Vessel Hull

In PRAM, the ship's hull is assumed to be porous, allowing PCBs released into the internal vessel compartment to freely move to the outside of the vessel, as a function of the external water current. This not does accurately reflect reality, since the ship's hull is actually constructed of thick steel plates. The assumption of a porous hull is likely a conservative assumption, since PCBs are allowed to flow out of the vessel into the receiving marine ecosystem almost as soon as they are released into the vessel's interior, and the mass of PCBs within the vessel is assumed not to deplete over time. These assumptions are conservative.

2.4.3 Vessel's Interior Compartment

The vessel interior is assumed in the models to be one interior compartment, where PCBs released from PCB-containing bulk product materials remaining onboard the vessel are dissolved into marine water that has made its way into the vessel. After dissolving into the internal ship water, the PCBs are adsorbed or absorbed into suspended solids and dissolved organic carbon fractions in the water. It is obviously a simplification to assume that the interior of the vessel is one, large, unobstructed space. Aircraft carriers such as the ex-ORISKANY may have 5,000 separate compartments within the structure of the ship.

One question that reviewers have raised concerning this assumption is about whether one or more of the (actual) internal compartments of the vessel could accumulate released PCBs because a hatch had not been removed, or had not remained open, etc. This buildup could pose a hazard if, in the future, there were a compartment structural failure, and the concentration of PCBs built up in this internal compartment are released in a bolus or "pulse" to the external environment, causing unexpected human health or environmental risks.

In 2001, the URS modeler conducted calculations to simulate this scenario and found that a limited internal-compartment buildup and catastrophic failure would have little impact on the environment, or risk to human health, as compared to long-term, chronic release of PCBs from the vessel. This is due to several factors, including:

- the very large spatial footprint of the vessel itself (156 square meters on the ocean floor)
- the large volume of the vessel itself (53,800 cubic meters)

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[7]Draft Supplemental Human Health Risk Assessment for the ex-ORISKANY (June 2004).

- the large dilution volume of water immediately external to the ship (for example, within a 15-meter standoff from all sides of the ship)
- the fact that biouptake and bioaccumulation in fish and other organisms takes time

The time-dependence of biouptake and bioaccumulation, as compared with the relatively short time required for transport of solubilized PCB, indicated that a confined-space internal buildup of PCBs would have limited impact with regard to increasing overall PCB concentrations in the external environment should a catastrophic failure of the compartment occur.

2.4.4 Water Column Turbulence vs. Existence of a Pycnocline

A significant issue in the development of the PRAM and TDM was whether the water column in the vicinity of the ex-ORISKANY artificial reef would be expected to be completely mixed, on a regular basis. The ex-ORISKANY's vertical profile will be significant, assuming that the vessel will be sunk in a vertical position, as planned. The ship's hull will present a "wall" extending from the sea floor up to about 27 meters below the surface. Above that, the "island" portion of the vessel will extend up another 15 meters or so. If ocean currents run perpendicular to the sides of the vessel, they will be lifted upward, causing an upwelling of water that will mix the water above the vessel. If ocean currents are perpendicular to the bow or stern of the vessel, less, but still significant, turbulence could occur.

In addition to the turbulence that can be expected to be caused by the vessel, there is evidence that there is naturally occurring turbulence in offshore Florida waters that may be expected to occur in the LAARS where the ex-ORISKANY is proposed to be deployed.[8] Nonetheless, PRAM and TDM assume that there is a pycnocline, existing at approximately 15 meters below the water's surface, that acts to retard PCB diffusion into the upper water column (water above the pycnocline) from the lower water column (water below the pycnocline) into which PCBs are initially released from the sunken vessel. This was a purposeful decision, based on considerations of the conservativeness that should be introduced into the models. Recognizing that there are few, if any, physical barriers in the marine environment, there was considerable discussion between the USEPA, Florida, and the Navy about the size of the "zone of influence" (ZOI), or the exposure volume, that should be used in modeling PCB distribution into the marine environment. The assumption of a pycnocline, to bound the area into which PCBs are initially distributed, was considered a reasonable way to approach the issue of limiting the exposure volume. Moreover, based on Escambia County divers' experience, as relayed in TWG meetings, a pycnocline is often observed in Florida marine waters.

[8] At the November, 2004 TWG meeting and in teleconferences between USEPA, State of Florida, and Navy during November-December 2004, ECMRD representatives noted that turbulence is naturally occurring in offshore Florida waters, and presented a study that characterized turbulence.

2.4.5 Physical Properties of PCB and PCB Homologs (K_{ow} and K_{oc})

The models require input data on a variety of physical and chemical properties for each compound of concern. Small changes in some of these parameters can result in significant differences in estimated abiotic concentrations, and hence the subsequently estimated biota concentrations and human and ecological risks. The octanol-water partition coefficient (K_{ow}) of hydrophobic organic compounds such as PCBs is a parameter that significantly affects partitioning and bioaccumulation properties. Most risk assessments rely on deterministic calculations with parameter values taken from tabulations compiled either by the USEPA or other regulatory agencies, from literature sources, or from a combination of these. In PRAM and the TDM, the K_{ow} values used the PCB homologs (mono- through deca) were compiled from values published in scientific literature.

We recognize that there is a wide range of tabulated K_{ow} values in the published literature and regulatory agency sources. For example, a recent paper by Linkov et al.[9] presented at the Fourth SETA Word Congress[10] conference found that, among different regulatory agencies, and even between USEPA offices, the recommended K_{ow} values for total PCBs and for Arochlor 1254 were significantly different. Log K_{ow} values for total PCBs ranged from 3.9 to 8.23 and Log K_{ow} values for Arochlor 1254 ranged from 3.34 to 6.98. The authors concluded that their review of K_{ow} values available in USEPA-recommended databases revealed a range of values that covers more than four orders of magnitude for total PCBs and more than three orders of magnitude for Arochlor 1254.

<u>Other Model Simplifications</u>

There are a number of simplifications and assumptions in TDM not identified in Section 2.2 (Model Issues) that result in uncertainties in model output:

- In TDM, DOC, TSS and sediment are treated as bulk material with no internal structure or distinct chemical properties. For example, PCB flux through sediment pore water is not explicitly addressed, but is assumed to contribute to net sediment PCB flux.

- In TDM, independent adsorption and desorption processes are combined together to yield net PCB adsorption or desorption. Adsorption and desorption kinetics are assumed to be

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[9] Igor Linkox, Michael Ames, Edmund Crouch, Uncertainty in K_{ow}: Implications for Risk Assessment and Remedial Decisions, Peer Review Draft, presented at 4th SETAC World Conference, 14-18 November 2004.

[10] Fourth SETAC World Congress, 25th Annual Meeting in North America,14-18 November 2004

the same, reaching 99% equilibrium concentrations in 24 hours, though the Di Toro and Horzempa (1982) paper only addressed adsorption rates.

The same kinetics are also applied to all PCB homologs, though the same paper only studied a single hexachlorobiphenyl. Since the kinetics are fast relative to the release periods, modeled PCB concentrations in stationary sediment would not be impacted. The kinetics are short relative to water, DOC and TSS residence time in the model domain however. Increasing or decreasing adsorption/desorption rates would increase or decrease the PCB load in DOC and TSS relative to water, respectively.

PRAM and TDM are constructed to use individual PCB homologs to model abiotic transport and bioaccumulation. K_{ow} and K_{oc} values from scientific literature for each PCB homolog (mono- through deca-) were found. Thus we have attempted to avoid the controversy associated with the wide range of K_{ow} and K_{oc} values that have been recommended to total PCBs.

This section details the methods used to derive PCB tissue concentrations in a variety of representative biological organisms that are assumed to be associated with the ex-ORISKANY reef during the transient release period (0 to 2 years following deployment. Time-averaged TDM outputs are used as inputs to the PRAM's biotic food-web module to predict biotic tissue concentrations at discrete time and distance intervals. These biotic tissue concentrations may be used to assess ecological risks associated with the artificial reef during the transient release period. In addition, this section describes the methods used to derive estimates of human health risks, based on time-weighted averages of fish tissue PCB concentrations during the transient release period. These risk estimates may be used to assess subchronic human health risks associated with the transient release period at the ex-ORISKANY reef.

3.1 GENERAL DESCRIPTION OF APPLICABLE PRAM MODULES & ALGORITHMS

As described in the PRAM document (NEHC/SSC-SD, 2005), the PRAM (steady-state) model [PRAM] consists of three modules that are interconnected, in that the calculated outputs from the initial module become inputs for use by mathematical algorithms in the subsequent modules. The interdependence of the modules is shown in Figure 3-1. The modules in the PRAM include:

- Abiotic module: The PRAM abiotic module is a steady-state fugacity model. It uses the geometry of the modeled environment as well as assumptions about thermodynamic equilibrium and processes to calculate concentrations of PCBs in various media in the vicinity of the ex-ORISKANY reef, based on known loads of PCBs in shipboard materials and material-specific leach rates.

- Biotic food web-module: A biological system within the vicinity of the future ex-ORISKANY reef is modeled as consisting of trophic level (TL) I through IV species, resident in pelagic, benthic, and reef communities. Organism-specific bioenergetics and PCB biouptake and bioaccumulation algorithms are used to calculate biotic PCB concentrations for representative organisms included in the food web.

- Risk Characterization module: The Human Health Risk Assessment (HHRA) module in PRAM uses standard USEPA risk equations and algorithms to estimate cancer risks and non-cancer hazards from a fish-ingestion pathway. Drawing from PRAM's biotic food web-module, which contains six organisms (TL III and IV species) that are considered targeted sports fish, it utilizes the calculated whole body PCB concentrations for these 6 representative species to quantitatively evaluate the risks to recreational anglers and their families (i.e., children) from consumption of the sports fish.

The PRAM biotic food web-module and the risk characterization module were utilized to evaluate potential bioaccumulation and human health risks and hazards during the transient release period at the ex-ORISKANY reef. The abiotic model inputs to the PRAM, typically provided by the PRAM abiotic module, were instead provided by the TDM outputs, as further described below, to model the biouptake/bioaccumulation effect in the transient PCB release period.[11]

3.1.1 Potential Biota Based on Spatial and Temporal Considerations

In contrast to the pelagic and benthic communities, which are considered fully developed communities at the time of sinking, the reef community associated with the ex-ORISKANY reef is expected to take time to colonize and develop. The progression of the colonization of the ex-ORISKANY Memorial Reef is very difficult to predict with any degree of detail. However, certain generalities apply such that a qualitative description may be made.

Using the diets and water exposure assumptions presented in the PRAM 1.4 Documentation (May, 2005), a diet progression scenario was developed to suggest:

1. Reef-associated predators will be likely to colonize the reef almost immediately after the sinking of the vessel due to its attractiveness, as shelter, to these animals.

2. These predators will prey upon other organisms attracted to the reef as well as organisms present prior to the sinking of the vessel (i.e., pelagic and benthic community organisms).[12]

3. As the reef is progressively colonized, these predators will gradually shift their diets from primarily pelagic and benthic community prey to reef-associated prey items that appear on the artificial reef.

While this is a simplification of both the progression of the reef development and the trophic dynamics that will become established, it allows a reasonable characterization of food chain exposure that may take place during the early life history of an artificial reef.

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[11] As discussed in earlier sections in this document, the objective is to assess human health and ecological risks during the transient release period. The data necessary for these assessments are PCB concentrations in biota. Since biota uptake/bioaccumulate PCB differently based on time, distance, and diet-water exposures, biota data must be predicted, and then time-weight averaged for use in the risk assessments for the exposure period of interest. Sections that follow are intended to bring forth this concept of data acquisition.

[12] There is good evidence of this phenomenon as reported by Bortone et al. (1998).

3.2 DIET PROGRESSION AS A FUNCTION OF REEF COLONIZATION & DEVELOPMENT

To account for the change in community structure and dynamics during the initial period after the vessel is sunk, an illustrative food web scenario has been developed (Table 3-1). The time-variable dietary composition for representative organisms is used to simulate the PCB exposures, via diet, that these organisms will experience. Through the TWG represented by biologists and scientists from the State of Florida, USEPA, and the Navy, a perceived dietary progression for the reef consumers was developed for use in this purpose. As indicated in Table 3-1:

- The dietary composition of reef-obligate forms such as sessile filter feeders (TL II) and invertebrate omnivores (TL II) is assumed not to progress over time. These organisms are significant for PCB trophic transfers in the early stages of reef colonization due to their close proximity to the reef. Their colonization of the reef drives the subsequent dietary progression of predators under this reef development scenario.

The dietary progression identified in Table 3-1 is based on a series of time intervals thought to reflect potential changes in the reef communities. The progressive food web starts at day 1 after sinking (day 1 is considered as starting at 12 hours post-sinking, and continuing through the next 24 hours) and progressing through 1 week, 2 weeks, 1 month, 6 months, 1 year, and 2 years after vessel deployment. It is assumed that the community structure and PCB release rates will have both reached a steady-state condition at day 730 (i.e, at the 2 year mark).

3.3 WATER EXPOSURES FOR REPRESENTATIVE BIOTIC FOOD WEB ORGANISMS

PCB transfers from uptake through water across biological barriers is an important exposure route for biological organisms. Both PRAM and TDM assume that there are three different water compartments associated with the marine environment surrounding a sunken vessel into which PCBs will be distributed: an internal vessel water compartment, into which PCBs will first be released from the PCB-containing materials remaining onboard the vessel; an external, lower water column compartment (i.e., water below the pycnocline); and, an upper water column compartment (i.e., water above the pycnocline). Organisms that reside in the pelagic, reef, and benthic communities associated with the artificial reef will be exposed to these three different water compartments to a greater or lesser extent, depending on their dietary and habitation preferences and extent of reef fidelity. It is important to recognize the variety of potential exposures to these water bodies that different organisms might experience to calculate bioaccumulation for representative species.

Table 3-2 presents estimated percentages of time that the representative species in the PRAM Abiotic-Food web will be exposed to the three different water compartments assumed at the artificial reef. The estimates are based on research of the dietary and habitation preferences of the representative species (this is further discussed in the PRAM 1.4 documentation (NEHC/SSC-SD, May 2005).

3.4 TDM OUTPUT UTILIZED AS PRAM INPUT

Data management techniques were used to prepare the TDM output for use as PRAM input. An interface (macro) between TDM and PRAM was constructed to facilitate upload and use of the TDM data for use by the PRAM Biotic Food web module. The interface provides unit conversion and time averaging. Manipulation of the TDM data sets is described in the following sections.

3.4.1 Compilation of TDM Data by Homolog Group

For use in the PRAM Biotic-Food web module, TDM outputs were provided as a series of Microsoft Excel ™ (Excel) files that provided time-averaged PCB concentrations in abiotic media at distance intervals of 0 to 15 meters, 0 to 45 meters, and 0 to 60 meters away from the sunken vessel. As described in Section 2, the TDM time domain was from 0 to 730 days after ship sinking, and the TDM distance domain was from 0 to 3000 meters from the sunken vessel. The TDM was constructed to estimate PCB concentrations in abiotic matrices at one minute time intervals, over the entire time domain, and at 15 meter distance intervals, over the entire distance domain. However, for the human health and ecological risks assessments it was recognized that 24 hour time intervals would be the finest resolution needed for determining abiotic PCB concentrations, and that the distance intervals closest to the sunken vessel would be most significant for determining exposures to reef-associated organisms. For these reasons, the TDM outputs provided for use in developing data for the human health and ecological risk assessments were for the specific distance intervals, 0 to 15, 0 to 45, and 0 to 60 meters away the sunken vessel, and for the following time-averaged intervals: daily (each 24-hour period, starting at day 1, through day 730); day 1 (24 hours), day 7 (the 6 days after day 1); day 14 (the 7 days after day 7); day 28 (the 14 days after day 14); 6 months (the 5 months after 28); 1 year (the 6 months after day 180); and 2 years (the 1 year period after day 365). TDM outputs (time-averaged PCB concentrations) were provided for each PCB homolog (mono- through decachlorobiphenyl)[13], and for total PCBs (as the sum of PCB homolog concentrations) in each of the abiotic media compartments (water, suspended solids, and dissolved organic carbon in the upper and lower water columns, and in the internal vessel compartment; and in sediment).

[13] There are no octachlorobiphenyl (cl-8) outputs, since none of the PCB-containing materials on the ex-ORISKANY were found to contain octachlorobiphenyl homolog.

Using the TDM outputs for the 0 to 2 year period, a file was created for each PCB homolog, and all of that particular homolog's data were placed into its associated file. Ten different sets of information were received for each homolog:

- PCB concentration in the water in the upper water column
- PCB concentration in the total suspended solids in the upper water column
- PCB concentration in the dissolved organics in the upper water column
- PCB concentration in the water in the lower water column
- PCB concentration in the total suspended solids in the lower water column
- PCB concentration in the dissolved organics in the lower water column
- PCB concentration in the sediment
- PCB concentration in the water internal to the ship
- PCB concentration in the total suspended solids internal to the ship
- PCB concentration in the dissolved organics internal to the ship

These data were used in place of the PRAM's abiotic module output. To supplement the TDM data, it was assumed that the PCB concentration in sediment pore water was equal to the PCB concentration in the lower water column.

3.4.2 Unit Conversions Applied to TDM Data

TDM data for the PCB concentrations in the water in the upper and lower water columns (above and below the pycnocline) and in the internal vessel compartment water are in concentration units of gram of PCB per gram of water. The PCB concentrations for all other constituents are in gram of PCB per gram of material. These data had to be converted for use in the PRAM model to milligram of PCB per liter of water (mg/L) and milligram of PCB per kilogram of material (mg/kg).

3.4.3 Temporal Average of TDM Data for Coupling with the Temporal Progressive Food Web

- The PCB concentration data from TDM were provided on a daily basis for three distinct areas around the ship (15 meters, 45 meters and 60 meters away from the edge of the vessel on all sides). Fifteen meters correlates with a ZOI of 2. The 45 and 60 meter distances were evaluated because they bracket the ZOI of 5 (approximately 50 meters) for evaluating PCB biouptake into the benthic and pelagic community organisms, the static food web used in the PRAM evaluation was assumed (Table 3-3), while for the reef community, the TDM data were coupled with the progressive food web (the Diet Matrix table).

PRAM Biotic-Food web calculations were performed for the following TDM scenarios:

Time Increment	Distance from the Ship (in meters)	PCB Homologs Included in the Calculation
Day 1	15	all PCB homologs (mono – deca)[14]
Day 1	45	all PCB homologs (mono – deca)
Day 1	60	all PCB homologs (mono – deca)
Day 7	15	all PCB homologs (mono – deca)
Day 7	45	all PCB homologs (mono – deca)
Day 7	60	all PCB homologs (mono – deca)
Day 14	15	all PCB homologs (mono – deca)
Day 14	45	all PCB homologs (mono – deca)
Day 14	60	all PCB homologs (mono – deca)
Day 28	15	all PCB homologs (mono – deca)
Day 28	45	all PCB homologs (mono – deca)
Day 28	60	all PCB homologs (mono – deca)
Day 180	15	all PCB homologs (mono – deca)
Day 180	45	all PCB homologs (mono – deca)
Day 180	60	all PCB homologs (mono – deca)
Day 365	15	all PCB homologs (mono – deca)
Day 365	45	all PCB homologs (mono – deca)
Day 365	60	all PCB homologs (mono – deca)
Day 729	15	all PCB homologs (mono – deca)
Day 729	45	all PCB homologs (mono – deca)
Day 729	60	all PCB homologs (mono – deca)

The incremental food webs were loaded into the PRAM calculation sheet. For the construction of the transient period Biotic-Food web module, a separate PRAM calculation sheet was developed, and tissue concentration results were tallied based on the particular incremental food web associated with the specific time interval and the specified distance from the ship. Since

[14] All PCB homologs except for octachlorobiphenyl (Cl-8). Octachlorobiphenyl homolog was not found in any of the PCB-containing materials on the ex-ORISKANY.

PCBs are mixtures of homolog groups that are different in their uptake/bioaccumulation potential, each PRAM calculation sheet includes calculations for all PCB homolog groups for the food web specific to the given time and distance intervals.

3.5 TRANSIENT RELEASE TISSUE CONCENTRATIONS

As described above, the PRAM Biotic Food web module calculates PCB accumulation within the modeled biological system. The biological system within the vicinity of the ex-ORISKANY memorial reef is modeled using a food web consisting of Trophic Level I through Trophic Level IV species. Pelagic, benthic, and reef organisms are included in the food web. PCB tissue concentrations calculated for each of the organisms in the food web have been tabulated for each of the scenarios detailed in the previous section. These results are provided in Appendix F. It is anticipated that these biotic PCB concentrations will be utilized in evaluating the potential ecological risks associated with the ex-ORISKANY reef. A description of the ecological risk assessment approach is presented in Section 5.

3.6 SUBCHRONIC HUMAN HEALTH RISK ESTIMATES

The PRAM's Human Health Risk Characterization module estimates cancer risk and non-cancer hazards associated with a fish consumption pathway. The PRAM's Biotic-food web contains six organisms (Trophic Level III and IV species) from the pelagic, reef and benthic communities that are considered edible and targeted sports fish. As such, consumption of these sports fish by anglers and their families (i.e., children) are quantitatively evaluated from the modeled data (see Section 4). For use in the risk characterization, time-weighted average fish tissue concentrations were calculated for each of the sports fish. The tissue concentrations calculated for each representative organism in the pelagic, reef, and benthic communities, for each specified time interval, are presented in Appendix F. The time-weighted averages were calculated by time-weighting the fish tissue concentrations calculated by PRAM's biotic food web module for each progressive time interval (i.e., day 1, days 2-7, days 7-14, etc.) by the relative length of time that the scenario's food web was applicable during the two year transient period.

The governing equation used for the time-weighted averaging of total PCB tissue concentrations is:

$$C_{ave} = \frac{\sum_{i=1}^{n}\left(C_i \times T_i\right)}{\sum_{i=1}^{n} T_i}$$

Where:

C_{ave} = time-weighted average of all total PCB tissue concentrations (mg/kg)

C_i = total PCB tissue concentration over time interval *i* (mg/kg)
T_i = duration of time interval *i* (i.e. time elapsed since the end of the preceding time interval) (days)
i = unique time interval (1 day, 1 week, 2 weeks, 1 month, 6 months, 1 year or 2 years)
n = number of unique time intervals

Average fish tissue concentrations were calculated for the 15 m, 45 m, and 60 m bins which roughly equate to the exposure zones used in the PRAM calculations when Zone of Influence multipliers (ZOIs) of 2 and 5 are used. The selection of the ZOIs for the PRAM is discussed in Section 3.3, of the PRAM 1.4 Documentation (NEHC, May 2005). Use of PRAM's Risk Characterization module to quantify the human health risk via the ingestion pathway of these sports fish is discussed in Section 4.

3.7 MODELING UNCERTAINTIES

This section presents uncertainties associated with the procedures used in integrating TDM data and applying the biotic food web module in PRAM to provide data for use in risk assessments.

Model uncertainty associated with the PRAM is discussed in Section 2.4 of the PRAM 1.4 documentation. Section 2.6.3 of that document describes the three PRAM biotic communities in relation to the modeled food web, generalized trophic structure, assemblage guilds, and relevance to PCB transfers. Within each community, "generalized" organisms, along with associated generalized diets and exposure profiles, are used to characterize each trophic level within the food web. Whereas the TDM is a transient model, the PRAM is a steady-state model. Therefore, higher trophic level fish tissue concentrations will be overestimated during the early life history of the reef because the bioaccumulation within the food web will be calculated as though the PCBs have been present in the environment for a longer period of time. The following modeling uncertainties were associated with the data acquisition regime presented in this section: are summarized below:

- By using the PRAM biotic food web model, it is conservatively assumed that biota exists in the pelagic and benthic environment very early in the establishment of the reef;

- The diet progression assumed (Table 3-1) is an approximation under normal conditions (other events, such as storms that may cause mass migration of fish to seek shelter, are not considered);

- The time-weighted averaging of TDM data is an approximation method; we have not compared how this method may differ from other possible averaging methods.

As previously discussed in Section 3.1, and shown in a block diagram in Figure 4.1, the TDM evaluation consists of 3 modules; abiotic module, the biotic food web module, and the risk characterization module. This section discusses the risk characterization model describing the methods used to assess acute and subchronic human health risks associated with exposures to PCBs at an artificial reef site during a transient PCB release period. As discussed previously, the term "transient release" refers to the release of PCBs under pre-steady state conditions. Based on results of the leach rate studies conducted by SPAWAR (SSC-SD, 2004) this period starts within 12 hours of sinking of the ship, and extends for approximately two years.

The leach rate studies conducted by SPAWAR/SYSCEN (SSC-SD, 2004) show that peak PCB releases from PCB-containing bulk product materials on ships occur during the first few weeks after immersion in sea water. After this peak release period, the release rates gradually level off. Based on findings of this study, results of the TDM, and the Site Conceptual Exposure Model (SCEM) (Figure 4-2) developed for this transient release period, exposure is potentially complete for recreational divers and anglers (receptors of concern).

The methodology used in the evaluation of human health risks during the transient release period is based on standard regulatory risk assessment procedures, as identified in the *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)* (RAGS) (USEPA, 1989). Specifically, the RAGS includes guidance on how to evaluate acute and subchronic risks, associated with exposure periods ranging from hours, days, and weeks, up to seven years. The transient PCB-release period at the ex-ORISKANY artificial reef site corresponds to short-term exposure periods, as identified above for the receptors of concern. These transient release periods (short-term exposure periods) can be sub-categorized into acute exposure periods (less than 90 days) and subchronic exposure periods (91 days to 2 years). While cancer risk, based on lifetime exposure assumptions, is typically the primary health concern associated with PCB exposure, non-cancer hazard can be more significant than cancer over acute and subchronic exposure periods.

Short-term hazard can be evaluated either quantitatively, if appropriate toxicity values are available, or qualitatively, if they are not available. For the ex-ORISKANY, a qualitative evaluation was performed for dermal exposure by divers over the acute (0 to 90 day) time period[15] when the PCB concentration in water is anticipated to be highest, and a quantitative evaluation was performed for fish ingestion by an angler population over the 2 year period

[15] Divers may collect fish or shellfish on an infrequent basis and ingest such organisms; however, the exposure is expected to be much lower than for recreational anglers. Exposure from an incidental water ingestion pathway for the divers is also judged to be lower than for fish ingestion by anglers because PCB concentrations in fish are much higher than those in the water, and because anglers are expected to ingest a larger amount of fish than the amount of water incidentally ingested by the divers. Dermal and water ingestion pathways for anglers are judged to be complete and insignificant and incomplete, respectively.

immediately following sinking of the ship, as the sport fish and edible shellfish communities are becoming established at the artificial reef.

As discussed in RAGS (USEPA, 1989), human health risk assessments typically consist of four distinct components:

- Data evaluation
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

A discussion of the assumptions and algorithms for each of these components, as applied to the evaluations of acute and subchronic risks associated with an artificial reef site such as the ex-ORISKANY, is provided in the following sections.

4.1 ASSESSING ACUTE HAZARD – RECREATIONAL DIVER SCENARIO

Direct contact with water by recreational divers would be a potential exposure pathway of concern during the acute exposure period. Because there are no acute PCB toxicity values for dermal exposure, the risk evaluation will be performed qualitatively, with discussions of water concentrations, and the potential exposures by recreational divers

4.1.1 Data Evaluation

The data used for assessing short-term risks are average PCB concentrations predicted by TDM for various abiotic matrices. The TDM calculates site-specific, PCB homolog and total PCB concentrations in ten (10) matrices:

- water above the pycnocline (upper water column)
- total suspended solids (TSS) in the upper water column
- dissolved organic content (DOC) in the upper water column
- water below the pycnocline (lower water column)
- TSS in the lower water column
- DOC in the lower water column
- sediment

- internal vessel water
- internal vessel TSS
- internal vessel DOC

The TDM predicted abiotic media concentrations are dependent on a number of site-specific variables, including PCB source concentrations and mass of PCB source materials, material-specific and time-dependent leach rates of PCB homologs, physical properties of the reef and reef environment, and the modeled domains which are defined in the TDM as specific time-distance intervals or “bins” (elapsed times from sinking, and distances from the sunken vessel). For the acute and subchronic human health risk evaluations, the time intervals 0 to 90 days, and 0 to 730 days following ship sinking are appropriate periods to evaluate. Also, the distance intervals which define exposure areas closest to the ship are the appropriate ones to evaluate; the distance intervals 0 to 15 meters, 0 to 45 meters, and 0 to 60 meters away from the sunken vessel were chosen to represent the exposure areas of most concern for human health evaluation. The TDM outputs for average PCB concentrations in the abiotic matrices listed above, for the 0-2 year period after sinking (broken out into the two separate time intervals) of 0 to 90 days, and 91 to 730 days after sinking, and for distance intervals 0 to 15 meters, 0 to 45 meters, and 0 to 60 meters away from the sunken vessel are provided in Appendix G. Tables 4-1 and 4-2 indicate the average PCB concentrations in the various abiotic matrices for the above described time and distance intervals

To evaluate acute human health risks qualitatively, it is appropriate to examine the predicted concentrations of PCBs in water during the 0 to 90 day period after ship deployment, and review them in the context of exposure and potential uptake by the divers. The TDM output graphs provided in Appendix G (see Figures G-1 and G-4 for graphs of upper and lower water column concentrations) clearly indicate that total PCB water concentrations are higher during the 0 to 90 day period after sinking, as compared with the subsequent, 91 to 730 day period. (Other TDM output graphs, for example, those provided in Appendices B and C also indicate that PCB concentrations in water will be at their maximum in the first few weeks or early months after sinking.)

Table 4-1 provides the TDM predicted concentrations in abiotic media for the 0 to 90 day period, for the distance intervals of 0 to 15, 0 to 45, and 0 to 60 meters away from the sunken vessel in units of mg/L for water and mg/kg for solids. For the upper water column (water above the pycnocline) the PCB water concentrations are all in the range of 10^{-14} mg PCB/L of water. For the lower water column, the PCB concentrations are all in the range of 10^{-9} mg PCB/L of water. The results indicate that PCB concentrations in the lower water column will be at their maximum in the distance interval 0 to 15 meters from the sunken vessel, whereas the PCBconcentrations in the upper water column will be at their maximum in the distance interval 0 to 60 meters from the sunken vessel. The maximum concentration for sediment is 4.46 E-6 mg/kg.

It is interesting to note that the maximum predicted levels in matrices above the pycnocline are below the limits of detection (LODs) for the most sensitive detection method [10E-6 ug/L for water, and 5 to 10E-3 ug/kg for solids, under isotope dilution high-resolution gas chromatography/mass spectrometry (EPA Method 1668A, USEPA 1999)]. Some levels in matrices below the pycnocline (i.e., for internal ship compartment matrices) are at or above the LODs.

4.1.2 Exposure Assessment

This section presents a qualitative evaluation of exposure and risks for the recreational diver scenario, which focuses on the source, likelihood of occurrence of secondary source (environmental media), and the possibility of contact or exposure with contaminated sources by the divers.

4.1.2.1 Source, Release, and Transport

As discussed in Section 1.0, the sources of PCBs are residual PCB-containing bulk product materials that, after the vessel has been sunk, serve as a source of PCB at the artificial reef. The final source term report for the ex-ORISKANY (Appendix D) provides details on the masses for various PCB-containing bulk products on the ex-ORISKANY, and Appendix E provides details on how the total PCB leach rates for each material and the mass of PCBs released from each material per day were calculated. Table 4-3 presents the maximum concentrations (upper 95% UCL values) and masses of these bulk products aboard the ex-ORISKANY.

Per the SCEM, the PCB-containing bulk products collectively act as a primary source that release PCBs into water inside or immediately adjacent to the vessel through the physical process of leaching (molecular diffusion and solubilization). The released PCBs are expected to migrate or transport to other environmental media by advection, diffusion, and partitioning, creating secondary sources in other matrices (Section 2, and Appendices B and C).

4.1.2.2 Receptors and Routes of Exposure

During the first 90 days, the primary receptors of concern are recreational divers whose exposure to PCBs is through direct skin contact with water while diving. Because water PCB concentrations are at their maximum in the first few weeks after sinking, direct contact with water by divers would be an exposure route to be evaluated. To evaluate the potential significance of dermal exposure, the FWC Division of Marine Fisheries Management Dive

Assessment Team was consulted to identify realistic diving scenarios[16]. Several factors are likely to limit the amount of time an individual could spend diving the reef, particularly the depth of the reef and the amount of air a dive tank typically holds. For the ex-ORISKANY reef site, the Dive Assessment Team identified four different dive scenarios to describe maximum daily exposure at the ship, assuming individuals who dive 60 feet (where the top of the ex-ORISKANY's tower is located) or deeper. All scenarios assume a diver is using a standard 80 cubic inch aluminum tank, and is basing the amount of his/her time underwater on the U.S. Navy Dive Table #3 – 1999 Unlimited/No Decompression Limit table (Figure 4-3)[17]. That is, decompression will not be required before surfacing. The scenarios also assume that a second dive can be made in the same day, allowing for a recovery period at the surface before the second dive. The scenarios evaluated by the Dive Assessment Team are described below:

- Scenario 1: The maximum time someone could spend diving the reef using compressed air. This scenario assumes that a person will perform two dives to the top of the tower, which is located at 60 feet. The maximum allowable time for the first dive is 60 minutes. Assuming a 2.5-hour surface recovery period, the maximum time for the second dive is 30 minutes, for a daily total of 90 minutes.

- Scenario 2: A more reasonable estimate of time someone could spend diving the reef using compressed air. This scenario assumes that a person would dive a little deeper in order to explore part of the tower, instead of stopping at the very top of the tower. A first dive to 80 feet was assumed. At this depth a diver could remain no longer than 40 minutes. Assuming a 1.5-hour surface recovery period, the maximum time for the second dive to 60 feet is 24 minutes[18], for a daily total of 64 minutes.

- Scenario 3: An alternative more reasonable estimate of time someone could spend diving the reef using compressed air. This scenario assumes a first dive to 100 feet, which is still part of the tower, not the main body of the ship. At this depth a diver could remain no longer than 25 minutes. Assuming a 2-hour surface recovery period, the maximum time for the second dive to 60 feet is 30 minutes, for a daily total of 55 minutes.

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[16] An evaluation of likely maximum diving conditions at the ex-ORISKANY reef site was conducted in a meeting held on January 7, 2005, between Jon Dodrill, FWC and members of the FWC Division of Marine Fisheries Management Dive Assessment Team, Bill Horn and Keith Mille.

[17] The NOAA No-Decompression Air Table lists identical maximum "no decompression limits" as the U.S. Navy Dive Table #3 – 1999 Unlimited/No Decompression Limit Table.

[18] Because of nitrogen buildup in the bloodstream from a 80 foot dive, the second dive to 60 feet is of shorter duration (24 minutes) compared to scenario #1 (30 minutes).

- Scenario 4: An estimate of the amount of time someone could spend on a deeper dive, using the mixed gas Nitrox (32% oxygen). This scenario assumes a first dive to 120 feet, which is approaching the depth of the flight deck of the ship. At this depth a diver could remain no longer than 20 minutes. Assuming a 1-hour surface recovery period, the maximum time for the second dive to 90 feet is 120 minutes, for a daily total of 32 minutes.

For all scenarios described above, it was assumed that the ship would be sunk during the warmer summer months, and that divers would dive the reef 2 days per month. Given the likely presence of a mild thermocline at this time of year, divers would probably wear protective gear instead of wearing swimsuits only. Thin gauge (2-3 millimeters thick) neoprene wet suits with booties, with or without gloves, and without hoods are typically worn in this type of environment. Some restricted water circulation occurs against the skin inside the suit; however, most of this water enters the suit within the first few minutes of the dive on the way down (within the top 40 feet or so of the water column). Portions of the body covered by the suit, booties, gloves and mask would be exposed to water originating from the upper water column as the wetsuit filled, and would receive very little, if any, exposure to water originating from the immediate vicinity of the ship. The only body parts likely to be exposed to the lower water column (assuming an individual dives that deep) would be portions of the head, and possibly the hands.

4.1.3 Toxicity Assessment

USEPA has not developed PCB toxicity values (acute reference doses) for quantitatively evaluating short-term (acute) dermal exposure to PCBs by humans. Acute lethal doses for animals have been published in the literature, but these studies evaluated oral routes at very high doses. These studies are not relevant to dermal exposures at low concentrations in water. According to the Agency for Toxic Substances and Disease Registry (ATSDR), the most commonly observed health effects in people exposed to large amounts of PCBs are skin conditions such as acne and rashes. Studies in exposed workers have shown that long-term exposure to PCBs can result in changes in blood and urine that may indicate liver damage, however, the type of PCB exposure typically seen in the general population is not likely to result in skin and liver effects.

4.1.4 Risk Characterization

Because there are no acute PCB toxicity values for evaluating dermal exposure, the acute risk evaluation was performed qualitatively, with discussions of water concentrations, and likely exposures by divers, given the various diving scenarios discussed above. It should be noted that risks associated with the dermal exposure pathway are dependent on the amount of PCBs absorbed through skin. Such uptake or absorption is related to the frequency and duration of the exposure, and the amount of skin exposed. The higher these exposure parameters, the higher the exposure and associated risk or health concern.

The predicted PCB levels at the reef site are higher below the pycnocline than above the pycnocline. Given that the top of the vessel is at least 15 meters below the water surface, and the bulk of the vessel, where most of the PCBs reside, is more than 50 meters below the surface, it is unlikely that divers will spend much time in the lower water column. In addition, the air supply needed for various diving depths will severely limit the time a diver could spend in the water, such that exposure durations, and thus the hazards to divers, will be minimal.

As described in Section 4.1.2, a reasonable estimate of dive time in the vicinity of the ship's tower (60+ feet) or lower would be restricted to about 3 hours a month or less (depending on depth), and the amount of uncovered body surface area where exposure could occur is very limited. Given that the TDM estimates the maximum PCB water concentrations during this initial pulse release period to be in the low ng/L concentration range (3 to 6 $x10^{-14}$ mg/L in the upper water column and 3 to 4 x 10^{-9} mg/L in the lower water column) exposure would be expected to be minimal, particularly compared to subchronic exposure fish ingestion risks by anglers that are quantitatively evaluated in Section 4.2.4 and findings presented in Appendix F. The uncertainties associated with this risk characterization include:

- Predicted water concentrations, these simulated data are based on the TDM, which has its inherent uncertainties as discussed in Section 2.

- Frequency, duration, and exposure area. The frequency of diving within the first 90 days should be low, considering the information provided in Section 4.1.2.2. Although curiosity may drive additional dives, the vessel will not have fully colonized to provide biological resources that are attractive to divers. Moreover, divers are expected to move from one ZOI to another, although they are expected to spend the most time in the ZOI immediate to the vessel, above the pycnocline. The true degree of exposure based on frequency, duration, and location can only be assumed.

- Dermal contact with PCB-containing bulk products such as paints on the vessel. This is not evaluated. While PCBs are present in paint found in the vessel interior, they are not likely to be freely available, nor, given the depth and inherent safety concerns, is diving inside the vessel expected to occur on more than a very infrequent basis. Thus, the impact of this pathway is considered highly insignificant.

- Skin as a barrier for PCB uptake. The degree of uptake upon dermal contact with water containing PCB is not known. Divers may coat their skin with oily protectants as thermal insulation or against toxins in biota. The degree of impact of skin barrier and protectants relating to dermal uptake of PCBs in water cannot be defined at this time.

4.2 ASSESSING SUBCHRONIC HAZARD – FISH INGESTION SCENARIO

Uptake and bioaccumulation of PCBs by organisms at the artificial reef may result in the presence of PCBs in sport fish and shellfish. Therefore this exposure pathway is considered complete, and risk evaluation for this scenario is required.

It should be noted that the above scenario would only be plausible after a significant reef community has been established. In other words, "full biological resources" must be assumed in order that anglers can be assumed to be able to catch and ingest a reasonable amount of fish and shellfish during the first 2 years after the ship is sunk. This section presents a quantitative assessment of anglers from the fish ingestion exposure pathway under the above assumptions.

Because different organisms bioaccumulate PCBs differently from one another, and because anglers may preferentially target different species of sports fish, whole body PCB concentrations have been calculated for a variety of representative edible reef species. Subchronic human health risks associated with ingesting each representative edible reef species have been quantitatively evaluated. Prior to day 90, when water concentrations are predicted to be at their highest, the recreational anglers at the artificial reef are unlikely to experience any significant exposure, since few reef fish will have colonized the ship at this early stage. Also, those fish that are present would not likely contain as much PCB in their tissues as fish that will eventually live there for extended time periods, since the majority of the PCB accumulation in upper trophic level fish is derived from the food chain (i.e., from ingestion of lower trophic level organisms that have also been resident long enough to have accumulated PCB in their tissues). Thus, the results of the subchronic risk evaluation (described below) and chronic risk assessment (30 years of exposure) based on fish ingestion scenarios (presented in the PRAM-based SHHRA for the ex-ORISKANY) are considered the "worst-case" exposure scenarios for anglers.

4.2.1 Data Evaluation

Section 4.1.1 presents the data evaluation for the abiotic matrices, which are based on the TDM. This section focuses on the risk assessment approach and how PCB concentrations in biota are developed, using the PRAM biotic food web and risk assessment modules from PRAM to support the quantitative risk evaluation.

4.2.1.1 Diet-Water exposure and the PRAM BioticFood Web

As described in Sections 2 and 3, the TDM calculates time and distance specific, PCB homolog and total PCB concentrations in abiotic matrices (water, TSS, DOC, and sediment) in the marine environment surrounding the ex-ORISKANY reef during the transient release period. The time and distance-specific abiotic media concentrations calculated with the TDM can be used, in conjunction with the PRAM biouptake and bioaccumulation algorithms, to estimate whole body tissue concentrations for all ten PCB homologue groups and for total PCBs in various pelagic, benthic and reef organisms.

The TDM can estimate the abiotic media concentrations on a minute-per-minute basis, or on a daily (24-hour averaged) basis, for the model time domain of up to two years after sinking. While it is feasible to derive whole body PCB concentrations for representative reef species on a daily basis (i.e., for 730 consecutive days) using the PRAM biouptake and bioaccumulation algorithms, the very large amount of resultant data points makes this approach impractical. Time averaging periods used to calculate the biotic concentrations were chosen based on the following considerations:

- Because it takes time for an artificial reef to develop, all of the components of a reef community that supports the food chain will not be present immediately after the vessel is sunk. In particular, for higher trophic level organisms that feed on lower trophic level organisms, a significant portion of the diet during the initial stages of reef development may be from off-reef sources.

- Recreational anglers will likely fish the artificial reef more frequently when significant fish populations have taken up residence at the reef. Significant reef fish populations will likely be established at the reef once the reef has been sufficiently colonized to provide a complete food chain.

- While PCB concentrations in water reach their peak in the first few weeks after sinking, and in areas closest to the sunken vessel, leading to significant exposures to fish from gill uptake and from direct body exposure to water, diet is the most significant source of exposure to PCBs when diet sources contain PCBs.

Based on discussions with USEPA and Florida, and in light of the above considerations, a progressive "Diet Matrix" table was developed, based on professional judgment and consensus of the Biology Working Group in the TWG, to assist in determining the appropriate time periods for which to evaluate whole body tissue concentrations in representative reef species during the transient release period. The "Diet Matrix" is presented in Table 3-1. As indicated on the table, it was determined that PCB bioconcentrations in representative reef species would be determined at days 1, 7, 14, and 28 after reef deployment, and for 6 months, 1 year, and 2 years following deployment.[19]

Tables 4-1 and 4-2 indicate the average total PCB concentrations in abiotic media calculated by the TDM for the periods 0 to 90 days after deployment and from 91 days through 2 years after deployment. Whole body tissue concentrations calculated from the abiotic media data are presented in Appendix F for representative species from the benthic, reef and pelagic communities.

Because different organisms bioaccumulate PCBs differently from one another, and because anglers may preferentially target different species of sports fish, the risk evaluation calculated cancer risks and non-cancer hazard indices for the following representative reef species groups:

- Benthic Fish (Trophic Level [TL] IV Benthic Predator)
- Benthic Invertebrates (TL III Benthic Invertebrate Foraging Predator)
- Pelagic Fish (TL IV Pelagic Predator)
- Reef Fish (TL IV Reef Predator)
- Reef Fish (TL III Reef Vertebrate Forager)
- Reef Invertebrate (TL III Reef Invertebrate Forager)

These groups were chosen as containing targeted sports fish, as well as representing the groups with greatest potential for PCB biouptake/bioaccumulation. The applicability of each group will vary by reef site, based on variations in depth, temperature, local species, fishing preferences of local angler populations, etc., and should be evaluated on a site-specific basis. Table 4-4 indicates the types of sports fish that would be associated with each of the representative biological groups defined above.

4.2.2 Exposure Assessment

Discussion presented in Section 4.1.2 concerning the source, release/transport, and receptor/route exposure is applicable to this section except that:

- The tertiary source will be the biota species when bioconcentration and bioaccumulation have occurred at the reef site.

[19] Determining the body burdens of representative reef species that would occur at these time intervals may be useful in evaluating whether there are any potential adverse impacts to the reef biota, for example, in an ecological risk assessment, as well as for establishing the tissue concentrations of fish prey items.

- The receptors of concern are recreational anglers, which include the adults and children of the anglers.

- The exposure pathway of concern is fish ingestion under subchronic exposure conditions.

4.2.2.1. Exposure Scenarios

The two exposure scenarios are summarized below:

In the first 90 days of the sunken vessel, the recreational anglers at the artificial reef are unlikely to experience any significant exposure, since few reef fish will have colonized the ship at this early stage. Also, those fish that are present would not likely contain as much PCB in their tissues as fish that will eventually live there for extended time periods, since most of the PCB accumulation in upper trophic level fish is derived from the food chain (i.e., from ingestion of lower trophic level organisms that have also been resident long enough to have accumulated PCB in their tissues). Thus, the results of the subchronic risk evaluation (described below) and chronic risk assessment (30 years of exposure) based on fish ingestion scenarios (presented in the PRAM-based SHHRA for the ex-ORISKANY) are considered the “worst-case” exposure scenarios for anglers.

The angler scenario assumes that the high-end exposure angler would be a local resident who fishes the reef regularly over an extended time period (2 years), and that the angler’s family members (children and adults) eat the fish caught on the reef. In estimating the subchronic hazard for the recreational angler, both the reasonable maximum exposure and central tendency exposure scenarios will be evaluated. The RME and CTE exposures are based on upper and mean fractional fish ingestion specific to the ex-ORISKANY reef, derived from fish consumption surveys conducted in Escambia County, and on upper and mean daily fish ingestion rates (g/day), derived from the *EPA Exposure Factors Handbook* (USEPA, 1997)

4.2.2.2. Exposure Parameters

All exposure parameters (i.e., ingestion rate, body weight, exposure frequency, etc.) used to quantitate exposure to this receptor will be identical to those used in the chronic hazard evaluation, except for exposure duration. The exposure duration used for the subchronic evaluation will be two years. Table 4-5 lists the exposure parameters that will be used in the subchronic risk assessment.

Most of the exposure parameters used to define exposure by anglers, identified below under Risk Characterization, are standard USEPA default values that would apply to any reef site. Two parameters, Fraction of Fish Ingested (FI) and Fish Ingestion Rate (IR), are site-specific input values. For the ex-ORISKANY artificial reef site, an FI term was derived based on a Fish Consumption Survey conducted by the Escambia County Marine Resources Division (ECMRD, 2004; NEHC, 2004)[20]. The FI value defines the relative proportion of fish an angler eats from the reef relative to the total amount of fish in his or her diet from all sources (caught in other fishing areas, purchased at stores, etc.). (For other artificial reefs, in the absence of site-specific information, the FI value in PRAM can be set as 1.0 [i.e., a highly conservative assumption that the reef is the only source fish in a person's diet]). The IR value reflects variation in the amount of fish various populations consume in different regions of the United States. USEPA-recommended, region-specific fish ingestion rates, as reported by the National Marine Fisheries Service (NMFS, 1993), can be found in Table 10-52 of the *Exposure Factors Handbook* (USEPA, 1997). For the ex-ORISKANY site evaluation, the IR value for the Gulf States is used. Exposure parameters used in the ex-ORISKANY risk evaluation are presented in Table 4-4.

4.2.2.3 Exposure Point Concentrations

Fish tissue concentrations used in the sub-chronic risk calculations were generated, as described in Section 4.2.1.1, based on estimated abiotic compartment PCB concentrations (water, DOC, TSS and sediment) generated from the TDM, and the bio-uptake and bioaccumulation algorithms from PRAM. The TDM assumes that there is no mass depletion of PCBs remaining on board the sunken vessel over time, and that the PCBs released from the vessel do not degrade over time (into, for example, lower-chlorinated PCBs). The TDM/PRAM predictions for whole body, total PCB concentrations in representative edible fish species are provided in Appendices F and H.

4.2.3 Toxicity Assessment

Discussion presented in Section 4.1.3 generally applies here, except that a USEPA published toxicity value has been identified and used. Hazard indices are calculated using a Reference Dose (RfD) of 5 x 10^{-5} mg/kg-day. This is the subchronic RfD for Aroclor 1254 that is listed in the USEPA Health Effects Assessment Summary Table (HEAST) (USEPA, 1997). For assessing carcinogenic risk, the slope factors published on USEPA's Integrated Risk Information System (IRIS) database (USEPA, 2005) of 2.0 $(\text{mg/kg/day})^{-1}$ and 1.0 $(\text{mg/kg/day})^{-1}$ are used to assess risks to these receptors under the reasonable maximum exposure (RME) and central tendency exposure (CTE) scenario, respectively, as recommended for food chain ingestion scenarios (USEPA, 2005).

[20] The derivation of the site specific FI term for the ex-ORISKANY site is described in Appendix L of the draft Supplemental Human Health Risk Assessment for the ex-ORISKANY (NEHC, 2004).

4.2.4 Risk Characterization

Following USEPA-recommended approaches, potential hazard indices are calculated under both RME and CTE conditions. The RME calculations use a number of upperbound exposure assumptions to provide a reasonable estimate of upperbound exposure among angler populations. The CTE calculations are based on a number of mid-range exposure assumptions, and are intended to represent risks and hazards to the typical angler.

Cancer risks and non-cancer hazard indicess were estimated for the ingestion of several different types of reef-associated fish species because different fish species have differing diet and habitation preferences, and thus experience different exposure regimes, depending on the area of the water column that they predominantly reside in, and their diet preferences. With regard to diet, an important consideration in evaluating reef fish exposures is progressive reef colonization during the transient PCB release period, and the associated diet progression.

Non-cancer hazard calculations (risk characterization) are performed using standard USEPA equations. Non-cancer hazard, based on child exposure only, is calculated using equation (1). Adult hazard calculations are presented in equation (2). For chronic exposures, adult hazard is typically based on combined adult and child exposure; however, for the subchronic evaluation, where the exposure duration is only two years, the "child + adult" calculation is not relevant.

$$(1)\quad HI_c = \frac{(C_f * IR_c * FI * EF * ED_c)}{(BW_c * AT_{nc\_child})} * \frac{1}{RfDs}$$

$$(2)\quad HI_a = \frac{(C_f * IRa * FI * EF * ED_a)}{(BW_a * AT_{nc\_adult})} * \frac{1}{RfDs}$$

Where:

HI_c = Hazard Index Child only (unitless)
HI_a = Hazard Index Adult only (unitless)
C_f = Chemical concentration in fish tissue (mg/kg) (calculated in PRAM)
IR_c = Fish ingestion rate in children (kg/day) (site-specific, daily average value)
IR_a = Fish ingestion rate in adults (kg/day) (site-specific, daily average value)
FI = Fraction of Fish Ingested (unitless) (site-specific value)
EF = Exposure frequency (days/year) (default value of 365 days/year; RME and CTE)
ED_c = Exposure duration for children (2 years, for transient release period)
ED_a = Exposure duration for adults (years) (2 years, for transient release period)
BW_c = Body weight of child (kg) (default value of 15 kg; RME and CTE)
AT_{nc_child} = Averaging time for non-carcinogens, child (default value of 365 days/year * ED_c; RME and CTE))

AT_{nc_adult} = Averaging time for non-carcinogens, adult (default value of 365 days/year * ED_a; RME and CTE))

RfD_S = Subchronic Oral Reference dose (5E-5 mg/kg-day)

Results of the subchronic hazard calculations, conducted with site-specific values for the ex-ORISKANY reef site, are provided in summary output sheets in Appendix H

Cancer risk, based on child exposure is presented in equation (3); cancer risk based on adult exposure, is presented in equation (4).

$$(3) \quad CR_c = \frac{C_f * IR_c * FI * EF * ED_c}{BW_c * AT_c} * SF$$

$$(4) \quad CR_a = \frac{C_f * IR_a * FI * EF * ED_a}{BW_a * AT_c} * SF$$

Where:

CR = Cancer risk (unitless)

AT_c = Averaging time for carcinogens (days) (default value of 25,550 days)

SF = Cancer slope factor (2.0 $[mg/kg\text{-}day]^{-1}$ RME; 1.0 $[mg/kg\text{-}day]^{-1}$ CTE)

Results of the subchronic risk calculations, conducted with site-specific values for the ex-ORISKANY artificial reef site, are provided in output sheets in Appendix H, and are summarized in Table 4-6. As shown in this table, the highest estimated cancer risks and non-cancer hazard indices were seen for the RME child scenario (all fish species). For this child scenario, the fish showing the highest risk and hazard was the trophic level IV reef predator, with an estimated cancer risk of $2.8x10^{-7}$, and non-cancer hazard index of 0.1. As shown in Table 4-6 for the ex-ORISKANY site, this category of fish corresponds to reef organisms such as groupers. Cancer risks and non-cancer hazard indices for trophic level III reef vertebrate foragers, represented by organisms such as triggerfish, are similar to the trophic level IV reef predators. For the RME child scenario, the cancer risk for ingestion of trophic level III reef vertebrate foragers is $2.1x10^{-7}$, and the hazard index is 0.07.

Cancer risks and hazard indices calculated for ingestion of all fish species are considered acceptable by USEPA criteria, indicating that ingestion of finfish and shellfish from the ex-ORISKANY reef during the first two years post-sinking is not likely to pose a health threat to angler populations.

4.3 CHARACTERIZING UNCERTAINTY

The uncertainties associated with this risk characterization include:

- Predicted abiotic concentrations are simulated data based on TDM, which has its inherent uncertainties as discussed in Section 2.

- Frequency, duration, and exposure areas. The frequency and duration of fish ingestion by recreational anglers are assumed. In addition, the fish caught and consumed are assumed to be associated with the reef and to have been exposed in particular exposure areas near the sunken vessel (areas corresponding to 0 to 15, 0 to 45, and 0 to 60 meters from the ship) when in reality, such fish are likely to have been migrated from other locations (such as estuaries or other reefs). In other words, the actual PCB body burdens are likely to lower than the modeled levels.

- The diet matrix table is employed, to estimate the presence of primary dietary sources at the reef. The first two years following deployment of the vessel as an artificial reef represents a very early period in the reef colonization process, and the rate at which colonization will occur at the ex-ORISKANY site cannot be accurately predicted.

- The subchronic toxicity value from HEAST (USEPA, 1997) used in this assessment is not likely to have gone through the vigorous review process that is required for toxicity values published on the USEPA IRIS. This value is therefore uncertain.

- Inherent uncertainties are associated with exposure parameters such as frequency, duration, FI, etc. The use of the RME and CTE approach in the risk evaluation provides information to assess how close these risk estimates are in terms of the impact of variability, assumptions, and uncertainties.

Output from the TDM and PRAM models will be used to evaluate ecological risks to the reef community and other ecological consumers that may feed and forage on the reef. TDM output will provide the concentrations of PCBs in the abiotic components of the environment. PRAM outputs will provide tissue concentrations in representative species expected in the food chain associated with the reef (Table 5-1). These data will be used to assess potential ecological risks to the assessment endpoints associated with the artificial reef (Table 5-2). Assessment endpoints include sediment and water exposure modeled by TDM, components of the food chain modeled by PRAM (Table 5-2a), as well as tertiary and avian consumers not directly modeled by PRAM (Table 5-2b). Risks from sediment and water exposures modeled by TDM will be evaluated by comparison to sediment and water benchmarks. Risks to assessment endpoints modeled in the PRAM food chain will be evaluated by comparison to benchmarks protective of tissue residue exposures. Risks to tertiary and avian consumers will be evaluated by benchmarks protective of dietary exposure.

PRAM output for the progressive food chain scenarios modeled to simulate potential food chain accumulation during the initial transient release after sinking will be evaluated using the estimated accumulation of PCBs modeled after 1 day, 1 week (7 days), 2 weeks (14 days), 1 month (28 days), 6 months (180 days), 1 year (365 days) and 2 years (729 days) for various distances from the hull (0 to 15, 0 to 45, and 0 to 60 meters). The modeled concentrations will be compared to the ecorisk benchmarks to evaluate potential acute and chronic exposures during the transient release period. The benchmarks, methodology, and procedures used to evaluate ecological risks associated with sinking the ex-ORISKANY are provided in the ecological risk assessment report (Johnston et al. 2005).

ATSDR 2001. Agency for Toxic Substances and Disease Registry (ATSDR). 2001.

Bortone, S.A., R.P. Cody, R.K. Turpin and C.M. Bundrick. 1998. The Impact of Artificial-Reef Fish Assemblages on their Potential Forage Area. Italian Journal of Zoology. 65(Supplement): 265-267.

CACI. 2004. Final Report – Polychlorinated Biphenyls (PCB) Source Term Estimates for ex-ORISKANY (CVA34).

ECMRD 2004. Escambia Country Marine Resources Division (ECMRD) and Florida Fish and Wildlife Commission (FWCC) Fish Consumption Survey, May-June 2004.

Di Toro, D.M. and L.M. Horzempa. 1982. Reversible and resistant components of PCB adsorption-desorption: isotherms. Environ. Sci. Technol. 16:594-602.

Fetter, C.W. *Contaminant Hydrology Section Edition* 1999. Prentice Hall, Inc. Upper Saddle River, New Jersey.

Johnston, R.K. et al. 2005 (in prep). An evaluation of ecological risks associated with sinking the ex-ORISKANY to create an artificial reef within the Escambia East Large Artificial Reef Site, Florida. Space and Naval Warfare Systems Center, San Diego, CA.

Law C.S., E.R. Abraham, A.J. Watson, M.L. Liddicoat. 2003. Vertical eddy diffusion and nutrient supply to the surface mixed layer of the Antarctic Circumpolar Current. J. Geographical Research 108(C8):3272.

Maidment, D.R. *Handbook of Hydrology.* 1992. McGraw-Hill Inc. New York, New York.

National Marine Fisheries Services (NMFS). 1993. Data Tapes for the 1993 NMFS presented to USEPA, National Center for Environmental Assessments.

NCCOSC 1994. Richter, K.E., a. Valkirs, C. Dooley, R. Gauthier, M. Stallard, and D.H. Rushworth 1994. Ecological analysis of deep sea sinking of Naval ships containing Polychlorinated Biphenyls (PCB) impregnated materials, White Paper. Naval Command, Control, and Ocean Surveillance Center, Research Development Test and Evaluation Division (NRaD), Environmental Sciences Division, Code 52, 4 March 1994, San Diego, CA

NEHC/SSC-SD 2005. Prospective Risk Assessment Model Version 1.4 Documentation. May

NEHC 2004. Supplemental Human Health Risk Assessment (SHHRA) for the ex-ORISKANY Artificial Reef (Draft), July, 2004. (Chapter 5 of SHHRA described the Prospective Risk Assessment Model).

PRAM. Version 1.3, 2004. Electronic copies of the Prospective Risk Assessment Model, Version 1.3, were provided to the Navy (NAVSEA), the USEPA and the State of Florida in July 2004.

SSC-CD 2004. SPAWAR/SYSCEN, San Diego, draft Final Report: Investigation of polychlorinated biphenyl (PCB) release rates from selected shipboard solid materials under laboratory-simulated shallow ocean (artificial reef) environments, October, 2004.

SSC-SD 2004. George R., C, In, R, K. Johnston, P.F. Seligman, R.D. Gauthier, and W. J. Wild, 2005 (in preparation). Investigation of polychlorinated biphenyl (PCB) release rates from selected shipboard solid materials under laboratory-simulated shallow ocean (artificial reef) environments. Draft Final Report. Space and Naval Warfare Systems Center, San Diego, CA.

Thibodeaux, L.J. *Environmental Chemodynamics: Movement of Chemicals in Air, Water, and Soil, Second Edition.* 1996. John Wiley & Sons, Inc. New York, New York.

Toole, J.M, K.L Polzin and R.W. Schmidt. 1994. Estimates of diapycnal mixing in the abyssal ocean. Science. 164:1120-1123

ToxFAQs for Polychlorinated Biphenyls (PCBs).

Turpin, R. 2004. Personal Communication from Captain Robert Turpin, Escambia County Marine Resources Division.

Weber, W.J. Jr., P.M. McGinley and L.E. Katz. 1991. Sorption phenomena in subsurface systems: concepts, models and effects of contaminant fate and transport. Wat. Res.25(5):499-52

USEPA 1989. United States Environmental Protection Agency (USEPA). 1989. Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A). EPA/540/1-89-002. December.

USEPA, 1997. Health Effect Assessment Summary Tables (HEAST).

USEPA 1997. United States Environmental Protection Agency (USEPA). 1997. Exposure Factors Handbook, Volume 2. Food Ingestion Factors. August. EPA/600/P-95/002Fb

USEPA 1999. United States Environmental Protection Agency (USEPA). 1999. Method 1668, Revision A: Chlorinated Biphenyl Congeners in Water, Soil, Sediment, and Tissue by HRGC/HRMS. December. EPA/821/R-00/002.

USEPA and State of Florida, 2004. Comments and responses to comments on the SHHRA, dated August 15, 2004.

USEPA. 2005.Integrated Risk Intergrated System (IRIS)

Table 2-1

Homolog Water-Organic Carbon Partitioning Coefficients Used in TDM

PCB homolog	K_{oc}
Monochloro	4.61×10^{3}
Dichloro	1.14×10^{4}
Trichloro	4.22×10^{4}
Tetrachloro	4.51×10^{4}
Pentachloro	8.61×10^{4}
Hexachloro	1.2×10^{6}
Heptachloro	2.19×10^{6}
Octachloro	2.85×10^{6}
Nonachloro	9.24×10^{6}
Decachloro	8.72×10^{7}

Table 3-1

Changing Dietary Preferences for the Reef Community During the First Two Years of Reef Development

			Suspended Solids (Epilimnion)	Suspended Solids (Hypolimnion)	Sediment	Phytoplankton	Zooplankton	Pelagic Planktivore	Attached Algae	Reef Sessile Filter Feeder	Invertebrate Omnivore	Reef Invertebrate Forager	Reef Vertebrate Forager	Infaunal Benthos	Epifaunal Benthos	Benthic Forager	Total
Sessile filter feeder (TL-II)																	
Day	1	day	0%	10%		80%	10%		0%								100%
Day	7	week	0%	10%		80%	10%		0%								100%
Day	14	2 week	0%	10%		80%	10%		0%								100%
Day	28	month	0%	10%		80%	10%		0%								100%
Day	180	6 mon	0%	10%		80%	10%		0%								100%
Day	360	yr	0%	10%		80%	10%		0%								100%
Day	720	2 yr	0%	10%		80%	10%		0%								100%
Invertebrate Omnivore (TL-II)																	
Day	1	day	0%	0%		0%	0%		80%	20%					0%		100%
Day	7	week	0%	0%		0%	0%		80%	20%					0%		100%
Day	14	2 week	0%	0%		0%	0%		80%	20%					0%		100%
Day	28	month	0%	0%		0%	0%		80%	20%					0%		100%
Day	180	6 month	0%	0%		0%	0%		80%	20%					0%		100%
Day	360	yr	0%	0%		0%	0%		80%	20%					0%		100%
Day	720	2 yr	0%	0%		0%	0%		80%	20%					0%		100%
Invertebrate Forager (TL-III)																	
Day	1	day		10%		0%	5%	5%	0%	0%	0%			50%	30%		100%
Day	7	week		10%		0%	5%	5%	0%	5%	5%			45%	25%		100%
Day	14	2 week		10%		0%	5%	5%	0%	10%	10%			35%	25%		100%
Day	28	month		5%		0%	5%	5%	0%	20%	20%			25%	20%		100%
Day	180	6 month		5%		0%	5%	5%	0%	30%	30%			15%	10%		100%
Day	360	yr		5%		0%	5%	5%	0%	30%	40%			10%	5%		100%
Day	720	2 yr		5%		0%	5%	5%	0%	35%	50%			0%	0%		100%
Vertebrate Forager (TL-III)																	
Day	1	day		0%		0%	0%	25%	0%	0%	0%	0%		10%	30%	35%	100%
Day	7	week		0%		0%	0%	25%	0%	0%	0%	0%		10%	30%	35%	100%
Day	14	2 week		0%		0%	0%	25%	0%	0%	0%	0%		10%	30%	35%	100%
Day	28	month		0%		0%	0%	25%	0%	5%	5%	0%		10%	25%	30%	100%
Day	180	6 month		0%		0%	0%	22%	0%	12.5%	12.5%	8%		15%	15%	15%	100%
Day	360	yr		0%		0%	0%	22%	0%	18%	12.5%	12.5%		12.5%	12.5%	10%	100%
Day	720	2 yr		0%		0%	0%	19%	0%	19%	15%	22%		12.5%	12.5%	0%	100%
Reef Predator (TL-IV)																	
Day	1	day		0%		0%	0%	20%	0%	0%	0%	0%	0%	0%	20%	60%	100%
Day	7	week		0%		0%	0%	20%	0%	0%	0%	0%	0%	0%	20%	60%	100%
Day	14	2 week		0%		0%	0%	20%	0%	0%	0%	0%	0%	0%	20%	60%	100%
Day	28	month		0%		0%	0%	20%	0%	0%	0%	0%	0%	0%	20%	60%	100%
Day	180	6 month		0%		0%	0%	20%	0%	0%	0%	10%	10%	0%	20%	40%	100%
Day	360	yr		0%		0%	0%	10%	0%	0%	0%	15%	25%	0%	10%	40%	100%
Day	720	2 yr		0%		0%	0%	0%	0%	0%	0%	15%	60%	8%	8%	8%	99%

Notes:
TL stands for Trophic Level

Table 3-2

Estimated Water Exposure by Pelagic, Reef and Benthic Biota

Water Exposures					
		Upper Water Column	Lower Water Column	Vessel Interior	Sediment Pore Water
Pelagic Community					
Phytoplankton (TL1)	Algae	100%			
Zooplankton (TL-II)	copepods	50%	50%		
Planktivore (TL-III)	herring	80%	20%		
Piscivore (TL-IV)	jack	80%	20%		
Reef / Vessel Community					
Attached Algae	Algae		100%		
Sessile filter feeder (TL-II)	bivalves (w/o shell`		100%		
Invertibrate Omnivore (TL-II)	urchin		80%	20%	
Invertibrate Forager (TL-III)	crab		70%	30%	
Vertibrate Forager (TL-III)	triggerfish		70%	30%	
Predator (TL-IV)	grouper		80%	20%	
Benthic Community					
Infaunal invert. (TL-II)	polychaete		20%		80%
Epifaunal invert. (TL-II)	nematode		50%		50%
Forager (TL-III)	lobster		75%		25%
Predator (TL-IV)	flounder		90%		10%

Table 3-3

Food Web Used to Evaluate Pelagic, Reef, and Benthic Communities Under Steady-State Conditions

	Suspended Solids (Epilimnion)	Suspended Solids (Hypolimnion)	Sediment[1]	Phytoplankton	Zooplankton	Pelagic Planktivore	Attached Algae	Reef Sessile Filter Feeder	Invertebrate Omnivore	Reef Invertebrate Forager	Reef Vertebrate Forager	Infaunal Benthos	Epifaunal Benthos	Benthic Forager	Total
Pelagic (open water associated organisms)															
Zooplankton (TL-II)	15%	15%		70%											100%
Planktivore (TL-III)	0%	0%		0%	100%			0%					0%		100%
Piscivore (TL-IV)				0%	10%	90%		0%	0%	0%	0%		0%	0%	100%
Benthic (sediment associated organisms)															
Infaunal Macroinvertebrate (TL-II)			50%	30%	20%		0%								100%
Epifaunal Invertebrate (TL-II)		0%	25%	30%	20%		0%					25%			100%
Benthic Forager (TL-III)		0%	5%	0%	0%	0%	0%					50%	45%		100%
Benthic Predator (TL-IV)		0%	2%	0%	0%	0%						20%	20%	58%	100%
Reef (reef associated organisms)															
Sessile filter feeder (TL-II)	0%	10%		80%	10%		0%								100%
Invertebrate Omnivore (TL-II)[3]	0%	0%		0%	0%		80%	20%					0%		100%
Invertebrate Forager (TL-III)		5%		0%	5%	5%	0%	35%	50%			0%	0%		100%
Vertebrate Forager (TL-III)		0%		0%	0%	19%	0%	19%	15%	22%		12.5%	12.5%	0%	100%
Reef Predator (TL-IV)		0%		0%	0%	0%	0%	0%	0%	15%	60%	8%	8%	8%	99%

Notes:

[1] The term "sediment" refers to any material within the sediment bed that supplies the biological energy input, including detritus/Particulate Organic Matter.

TL stands for Trophic Level

Table 4-1

Average Total PCB Concentrations in Abiotic Media During the Period 0 to 90 days After Sinking, for Distance Intervals 0 to 15 meters, 0 to 45 meters, and 0 to 60 meters from the Sunken Vessel

Time Period = 0 to 90 days after sinking

Distance from Sunken Vessel	0 to 15 meters	0 to 45 meters	0 to 60 meters
UWC water concentration (mg/L)	3.24E-14	5.30E-14	6.08E-14
UWC Suspended solids concentration (mg/kg)	5.59E-10	9.15E-10	1.05E-09
UWC Dissolved organic carbon (mg/kg)	3.73E-09	6.10E-09	7.01E-09
LWC water concentration (mg/L)	3.69E-09	3.18E-09	2.99E-09
LWC Suspended solids concentration (mg/kg)	6.39E-05	5.51E-05	5.17E-05
LWC Dissolved organic carbon (mg/kg)	4.26E-04	3.67E-04	3.45E-04
Sediment concentration (mg/kg)	4.46E-06	3.84E-06	3.61E-06
Inside vessel water concentration (mg/L)	2.87E-06	NA	NA
Inside vessel Suspended solids concentration (mg/kg)	4.97E-02	NA	NA
Inside vessel Dissolved organic carbon (mg/kg)	3.31E-01	NA	NA

Table 4-2

Average Total PCB Concentrations in Abiotic Media During the Period 91 to 730 days (2 years) After Sinking, for Distance Intervals 0 to 15 meters, 0 to 45 meters, and 0 to 60 meters from the Sunken Vessel

Time Period = 91 to 730 days after sinking

Distance from Sunken Vessel	0 to 15 meters	0 to 45 meters	0 to 60 meters
UWC water concentration (mg/L)	1.24E-14	2.02E-14	2.32E-14
UWC Suspended solids concentration (mg/kg)	2.49E-10	4.07E-10	4.68E-10
UWC Dissolved organic carbon (mg/kg)	1.66E-09	2.72E-09	3.12E-09
LWC water concentration (mg/L)	1.38E-09	1.19E-09	1.12E-09
LWC Suspended solids concentration (mg/kg)	2.75E-05	2.37E-05	2.22E-05
LWC Dissolved organic carbon (mg/kg)	1.83E-04	1.58E-04	1.48E-04
Sediment concentration (mg/kg)	3.94E-06	3.40E-06	3.19E-06
Inside vessel water concentration (mg/L)	1.08E-06	NA	NA
Inside vessel Suspended solids concentration (mg/kg)	2.14E-02	NA	NA
Inside vessel Dissolved organic carbon (mg/kg)	1.42E-01	NA	NA

where: UWC = Upper Water Column; LWC = Lower Water Column

Table 4-3

PCB Source Materials on the ex-ORISKANY: Masses, Concentrations, and Release Rates

PCB-Containing Material on the ex-ORISKANY	kg Material Onboard [1,2]	PCB Concentration (95% UCL) ppm	Fraction PCB	PCB Release Rate (ng/g-day) [3]	Daily PCB Release (ng/day) [4]
Ventilation Gaskets	1,460	33.5	3.14E-05	1,580	7.23E+04
Rubber Products	5,400	50.9	5.29E-05	1,580	4.50E+05
Electrical Cable	296,000	2,766.0	1.85E-03	279	1.53E+08
Bulkhead Insulation Material	14,400	587.7	5.37E-04	67,600	5.22E+08
Aluminum Paint	387,000	19.7	2.00E-05	11,100	8.62E+07
Total (All Materials)					7.62E+08

[1] Amount of material remaining after final vessel preparation (i.e., 72.6% BHI removal)

[2] Calculated masses of materials were rounded. Calculated amounts were: ventilation gaskets (1,459 kg); rubber products (5,397 kg); electrical cable (296,419 kg); aluminum paint (386,528 kg).

[3] Total PCB release rate is in units of ng PCB per gram of material per day

[4] PCB release rate is in units of nanograms of PCB released from the specified material per day

Table 4-4

Diet Summaries of Recreational Fishes Anticipated to Associate With Ex-ORISKANY[1]

Common Name	Scientific Name	Family	Main Forage/Prey[2]	Feeding Type[3]
blueline tilefish	*Caulolatilus microps*	Malacanthidae	benthic invertebrates	benthic predator (TL-IV)
greater amberjack	*Seriola dumerili*	Carangidae	pelagic nekton	pelagic piscivore (TL-IV)
lesser amberjack	*Seriola fasciata*	Carangidae	pelagic nekton	pelagic piscivore (TL-IV)
almaco jack	*Seriola rivoliana*	Carangidae	pelagic nekton	pelagic piscivore (TL-IV)
banded rudderfish	*Seriola zonata*	Carangidae	pelagic nekton	pelagic piscivore (TL-IV)
red snapper	*Lutjanus campechanus*	Lutjanidae	demersal fish/invertebrates	benthic and reef predator (TL-IV)
gray snapper	*Lutjanus griseus*	Lutjanidae	demersal fish/invertebrates	benthic and reef predator (TL-IV)
dog snapper	*Lutjanus jocu*	Lutjanidae	demersal fish/invertebrates	benthic and reef predator (TL-IV)
lane snapper	*Lutjanus synagris*	Lutjanidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
yellowtail snapper	*Ocyurus chrysurus*	Lutjanidae	demersal fish/invertebrates	benthic and reef predator (TL-IV)
wenchman	*Pristipomoides aquilonaris*	Lutjanidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
vermilion snapper	*Rhomboplites aurorubens*	Lutjanidae	mid-water macrozooplankton	pelagic planktivore (TL-III)
tomtate	*Haemulon aurolineatus*	Haemulidae	demersal invertebrates/fish	benthic predator (TL-IV)
white grunt	*Haemulon plumieri*	Haemulidae	demersal invertebrates/fish	benthic predator (TL-IV)
bank sea bass	*Centropristis ocyurus*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
rock hind	*Epinephelus adscensionis*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
speckled hind	*Epinephelus drummondhayi*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
yellowedge grouper	*Epinephelus flavolimbatus*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
red hind	*Epinephelus guttatus*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
goliath grouper	*Epinephelus itajara*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
red grouper	*Epinephelus morio*	Serranidae	demersal fish/invertebrates	reef and benthic predator (TL-IV)
warsaw grouper	*Epinephelus nigritus*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
Nassau grouper	*Epinephelus striatus*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
black grouper	*Mycteroperca bonaci*	Serranidae	demersal fish/invertebrates	reef and benthic predator (TL-IV)
yellowmouth grouper	*Mycteroperca interstitialis*	Serranidae	demersal fish/invertebrates	reef and benthic predator (TL-IV)
gag	*Mycteroperca microlepis*	Serranidae	demersal invertebrates/fish	benthic and reef predator (TL-IV)
scamp	*Mycteroperca phenax*	Serranidae	demersal fish/invertebrates	reef and benthic predator (TL-IV)
yellowfin grouper	*Mycteroperca venenosa*	Serranidae	demersal fish/invertebrates	reef and benthic predator (TL-IV)
gray triggerfish	*Balistes capriscus*	Balistidae	reef epifauna (foulers)	reef vertebrate forager (TL-III)

1. List is not comprehensive, but includes most sportfish managed as "reef fish" by the Gulf of Mexico Fishery Management Council (GMFMC) known or expected to occur in the Ex-*ORISKANY* vicinity, as well as additional non-managed species likely to be present, based on broad review of available literature on artificial reefs and natural hard bottoms of the West Florida Shelf. A few species were eliminated because of extremely catholic diets or lack of sufficient details to estimate "preferences."
2. Broad categories relating to spatial distribution and biological classification of principal dietary items of subadult and adult sportfish; for a given sportfish, this does not necessarily mean that it eats only the organisms indicated in only the habtitats indicated. Rather, the entries reflect the conservative assumptions of the PRAM.
3. The "best-fit" category trophic levels summarized in Table 5-1 of the Prospective Risk Assessment Model (PRAM) Version 1.4 Documentation (2005). Note that most snappers and groupers, even when in the vicinity of artificial reefs, appear to feed extensively on the seafloor adjacent to the reed as well as directly on the vertical structure.

Table 4-5

Exposure Parameters Used in the ex-ORISKANY Subchronic Risk and Hazard Calculations

Risk Inputs	Adult		Child	
	RME	CTE	RME	CTE
Ingestion Rate (kg/day)	0.0261	0.0072	0.0093	0.0026
Fractional Intake (unitless)	0.17	0.25	0.17	0.25
Exposure Frequency (days/year)	365	365	365	365
Exposure Duration (years)*	2	2	2	2
Body Weight (kg)	70	70	15	15
Averaging Time Non-Cancer (days)	730	730	730	730
Averaging Time Cancer (days)	25,550	25,550	25,550	25,550
Subchronic Reference Dose (mg/kg-day)**	5.0E-5	5.0E-5	5.0E-5	5.0E-5
Slope Factor $(mg/kg\text{-}day)^{-1}$	2.0	1.0	2.0	1.0

*subchronic exposure duration is 2 years

**subchronic reference dose is used in the subchronic hazard calculations

Table 4-6

Cancer Risks and Subchronic Hazard Indices Associated with TDM-Predicted Fish Tissue Concentrations for the ex-ORISKANY for the First Two Years Post-Sinking

RISK ESTIMATES	Total	Cancer Risk - Adult		Hazard Quotient - Adult		Cancer Risk -Child		Hazard Quotient - Child	
	PCB (ppm)	RME	CTE	RME	CTE	RME	CTE	RME	CTE
0-60 meters from ship									
Benthic fish (flounder)	0.00043	1.5E-09	3.1E-10	0.00054	0.00022	2.6E-09	5.2E-10	0.00090	0.00036
Benthic shellfish (lobster)	0.00012	4.3E-10	8.7E-11	0.00015	0.00006	7.1E-10	1.4E-10	0.00025	0.00010
Pelagic fish (jack)	0.00019	6.9E-10	1.4E-10	0.00024	0.00010	1.1E-09	2.3E-10	0.00040	0.00016
Reef fish TL-IV (grouper)	0.04540	1.6E-07	3.3E-08	0.05755	0.02335	2.7E-07	5.5E-08	0.09562	0.03879
Reef fish TL-III (triggerfish)	0.03547	1.3E-07	2.6E-08	0.04497	0.01824	2.1E-07	4.3E-08	0.07470	0.03031
Reef shellfish (crab)	0.02457	8.9E-08	1.8E-08	0.03114	0.01263	1.5E-07	3.0E-08	0.05174	0.02099
0-45 meters from ship									
Benthic fish (flounder)	0.00045	1.6E-09	3.3E-10	0.00058	0.00023	2.7E-09	5.5E-10	0.00096	0.00039
Benthic shellfish (lobster)	0.00013	4.6E-10	9.3E-11	0.00016	0.00006	7.6E-10	1.5E-10	0.00027	0.00011
Pelagic fish (jack)	0.00020	7.3E-10	1.5E-10	0.00026	0.00010	1.2E-09	2.5E-10	0.00043	0.00017
Reef fish TL-IV (grouper)	0.04544	1.6E-07	3.3E-08	0.05761	0.02337	2.7E-07	5.5E-08	0.09571	0.03883
Reef fish TL-III (triggerfish)	0.03550	1.3E-07	2.6E-08	0.04501	0.01826	2.1E-07	4.3E-08	0.07478	0.03034
Reef shellfish (crab)	0.02458	8.9E-08	1.8E-08	0.03116	0.01264	1.5E-07	3.0E-08	0.05177	0.02100
0-15 meters from ship									
Benthic fish (flounder)	0.00053	1.9E-09	3.9E-10	0.00067	0.00027	3.2E-09	6.4E-10	0.00111	0.00045
Benthic shellfish (lobster)	0.00015	5.3E-10	1.1E-10	0.00019	0.00008	8.8E-10	1.8E-10	0.00031	0.00012
Pelagic fish (jack)	0.00023	8.5E-10	1.7E-10	0.00030	0.00012	1.4E-09	2.9E-10	0.00049	0.00020
Reef fish TL-IV (grouper)	0.04556	1.7E-07	3.3E-08	0.05776	0.02343	2.7E-07	5.6E-08	0.09595	0.03893
Reef fish TL-III (triggerfish)	0.03560	1.3E-07	2.6E-08	0.04513	0.01831	2.1E-07	4.3E-08	0.07497	0.03041
Reef shellfish (crab)	0.02463	8.9E-08	1.8E-08	0.03122	0.01266	1.5E-07	3.0E-08	0.05186	0.02104

Table. 5-1 Data Provided by PRAM to be used in the ecorisk assessment. (A) Abiotic concentrations, (B) tissue concentrations.

(A) Abiotic PCB concentrations provided by TDM

Outside the Vessel		
	Freely dissolved in water	Upper and lower water column
	Suspended solids	Upper and lower water column
	Dissolved organic carbon	Upper and lower water column
	Bedded sediment	
Inside the Vessel		
	Freely dissolved in water	
	Suspended solids	
	Dissolved organic carbon	

(B) Tissue Concentrations for representative species in the food chain of the reef from Table 8 in PRAM documentation.

	Assessment Endpoint	Representative Species
Pelagic Community		
	Phytoplankton (TL1)	algae
	Zooplankton (TL-II)	copepods
	Planktivore (TL-III)	herring
	Piscivore (TL-IV)	jack
Reef / Vessel Community		
	Attached algae (TL-I)	algae
	Sessile filter feeder (TL-II)	bivalves
	Grazing / foraging omnivore (TL-II)	urchin
	Invertebrate forager (TL-III)	crab
	Vertebrate forager (TL-III)	triggerfish
	Predator (TL-IV)	grouper
Benthic Community		
	Infaunal invertebrate (TL-II)	polychaete
	Epifaunal invertebrate (TL-II)	nematode
	Forager (TL-III)	lobster
	Predator (TL-IV)	flounder

Table 5-2. Ecorisk assessment endpoints. (A) Assessment endpoints modeled directly by PRAM and TDM, (B) assessment endpoint evaluated by inferring risk from dietary exposures.

A. Assessment endpoints for reef community modeled by PRAM.

TISSUE CONCENTRATION (Provided by PRAM)	Representative Species
SECONDARY CONSUMERS	
Benthic/Forager (TL-III)	lobster
Benthic/Predator (TL-IV)	flounder
Reef/Forager (TL-III)	triggerfish
Reef/Predator (TL-IV)	grouper
Pelagic/Planktivore (TL-III)	herring
Pelagic/Piscivore (TL-IV)	jack
PRIMARY CONSUMER	
Benthic/Infaunal invert. (TL-II)	polychaete
Benthic/Epifaunal invert. (TL-II)	nematode
Reef/Sessile filter feeder (TL-II)	bivalves
Reef/Grazer (TL-II)	urchin
Pelagic/Zooplankton (TL-II)	copepods
PRIMARY PRODUCER	
Reef/Attached algae (TL1)	algae
Pelagic/Phytoplankton (TL1)	algae
SEDIMENT (Calculated with data from TDM)	
Bulk Sediment outside the vessel	
WATER (Calculated with data from TDM)	
Bulk Water Concentration outside the vessel	Upper and lower water column
Bulk Water Concentration inside the vessel	

Table 5-2. Ecorisk assessment endpoints. (A) Assessment endpoints modeled directly by PRAM and TDM, (B) assessment endpoint evaluated by inferring risk from dietary exposures (B) Assessment endpoints evaluated by inferring risk from dietary exposures.

DIET (provided by PRAM)	Representative Species
TERIARY CONSUMERS	
Dolphin	
Reef/Predator (TL-IV)	grouper
Reef/Vertebrate forager (TL-III)	triggerfish
Reef/Invertebrate forager (TL-III)	crab
Benthic/Predator (TL-IV)	flounder
Benthic/Forager (TL-III)	lobster
Pelagic/Planktivore (TL-III)	herring
Pelagic/Piscivore (TL-IV)	jack
Reef Shark/Barracuda	
Reef/Predator (TL-IV)	grouper
Reef/Vertebrate forager (TL-III)	triggerfish
Benthic/Predator (TL-IV)	flounder
Pelagic/Planktivore (TL-III)	herring
Pelagic/Piscivore (TL-IV)	jack
Sea Turtle	
Benthic/Forager (TL-III)	lobster
Reef/Invertebrate Forager (TL-III)	crab
Reef/Grazer (TL-II)	urchin
Reef/Sessile filter feeder	bivalves
AVIAN CONSUMERS	
Cormorant	
Pelagic/Planktivore (TL-III)	herring
Pelagic/Piscivore (TL-IV)	jack
Reef/Forager (TL-III)	triggerfish
Reef/Predator (TL-IV)	grouper
Benthic/Predator (TL-IV)	flounder
Herring Gull	
Pelagic/Planktivore (TL-III)	herring
Pelagic/Piscivore (TL-IV)	jack
Reef/Sessile filter feeder (TL-II)	bivalves
Reef/Grazer (TL-II)	urchin
Reef/Invertebrate Forager (TL-III)	crab
Reef/Vertebrate Forager (TL-III)	triggerfish
Reef/Predator (TL-IV)	grouper
Benthic/Epifaunal invert. (TL-II)	nematode
Benthic/Forager (TL-III)	lobster
Benthic/Predator (TL-IV)	flounder

Figure 1-1

TDM Input and Output, and Coupling with PRAM to Assess Risks

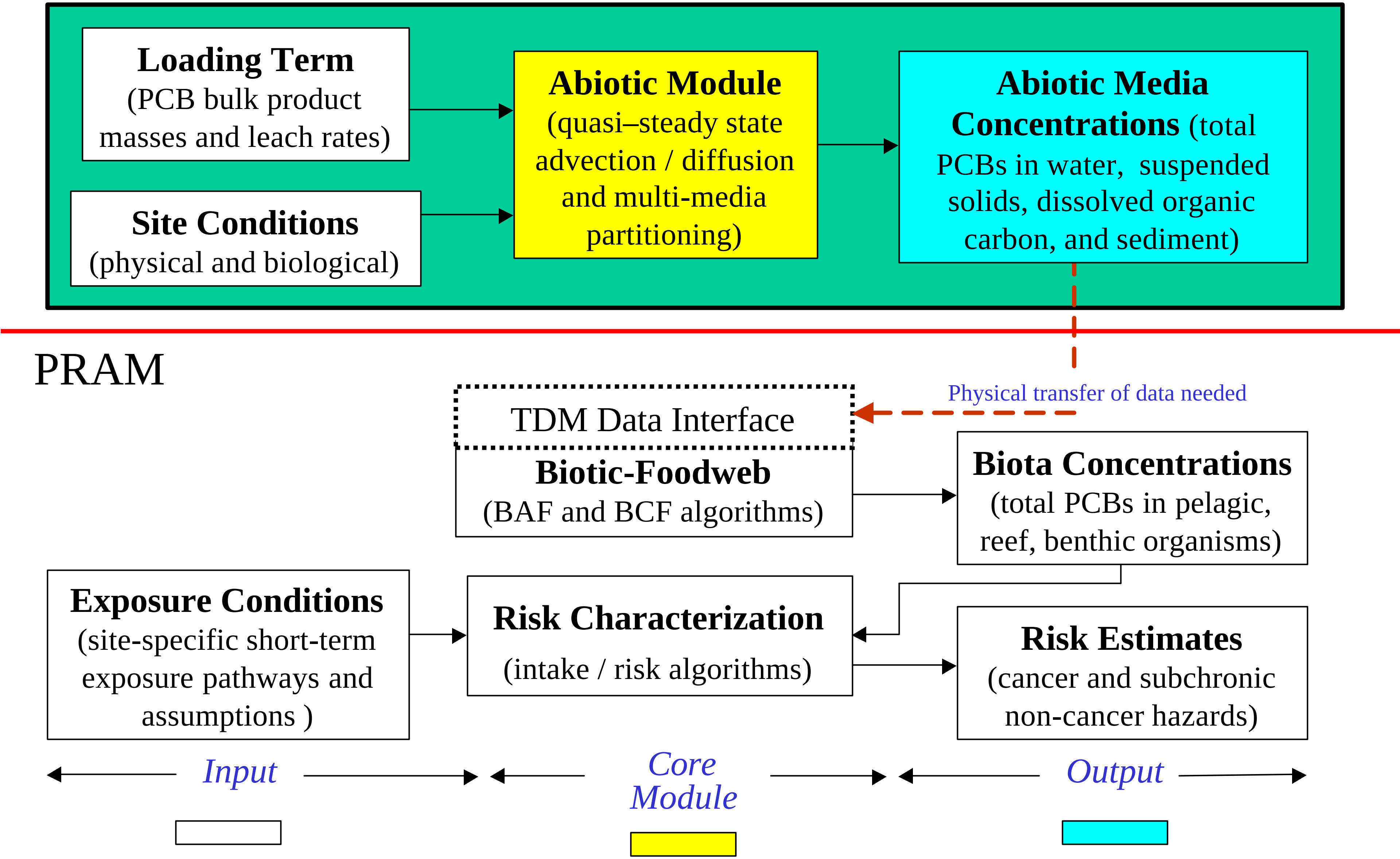


Figure 2-1

Mean 37 m Path Length at 0-15 m min^{-1} Equates to Mean Residence Time of 247 Minutes, 55% Equilibrium

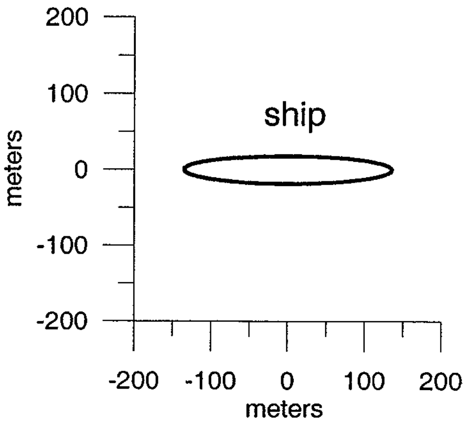


Figure 2-1a
Modeled Ship Geometry

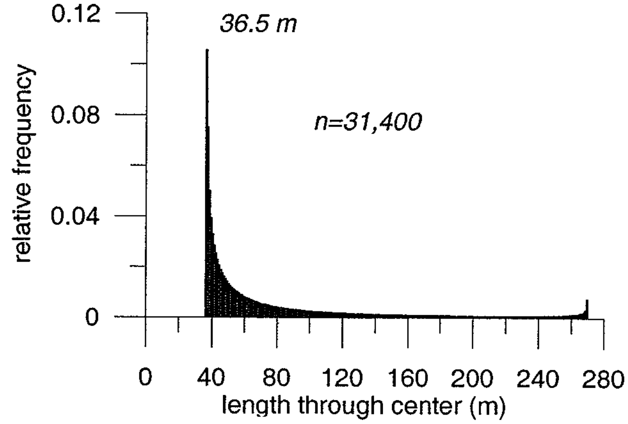


Figure 2-1b
Random Paths Through the Ship Center

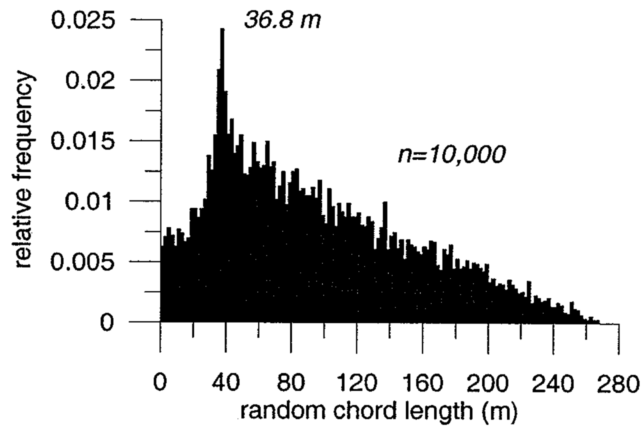


Figure 2-1c Random Ship Chords

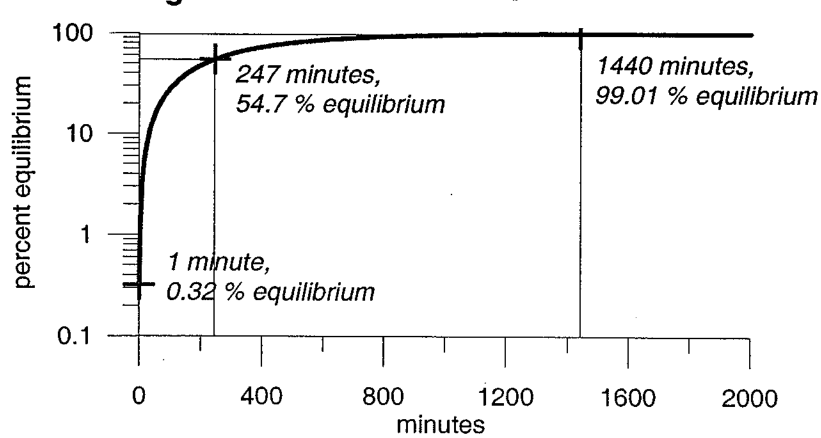


Figure 2-1d Assumed Kinetics of PCB Adsorption

Figure 2-2

Modeled Vertical Mixing of PCBs Across Pycnocline

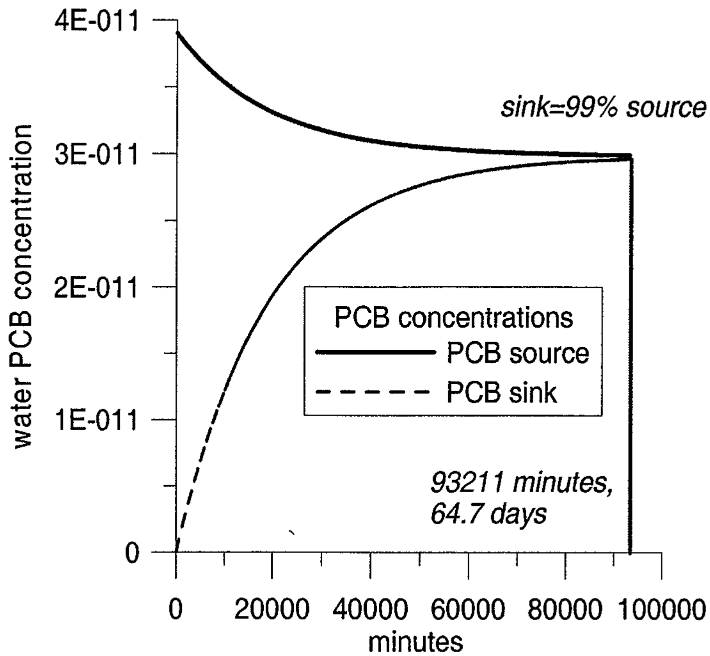


Figure 2-2a
Vertical Eddy Diffusivity K_z=0.1 cm^{2}sec^{-1}

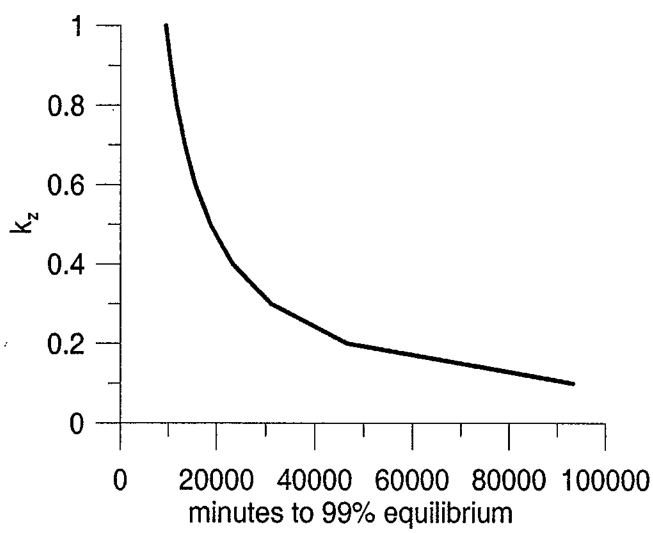


Figure 2-2b
K_z versus Time to 99% Equilibrium

Figure 3-1

Coupling of TDM Output with PRAM's Biotic-Foodweb Module

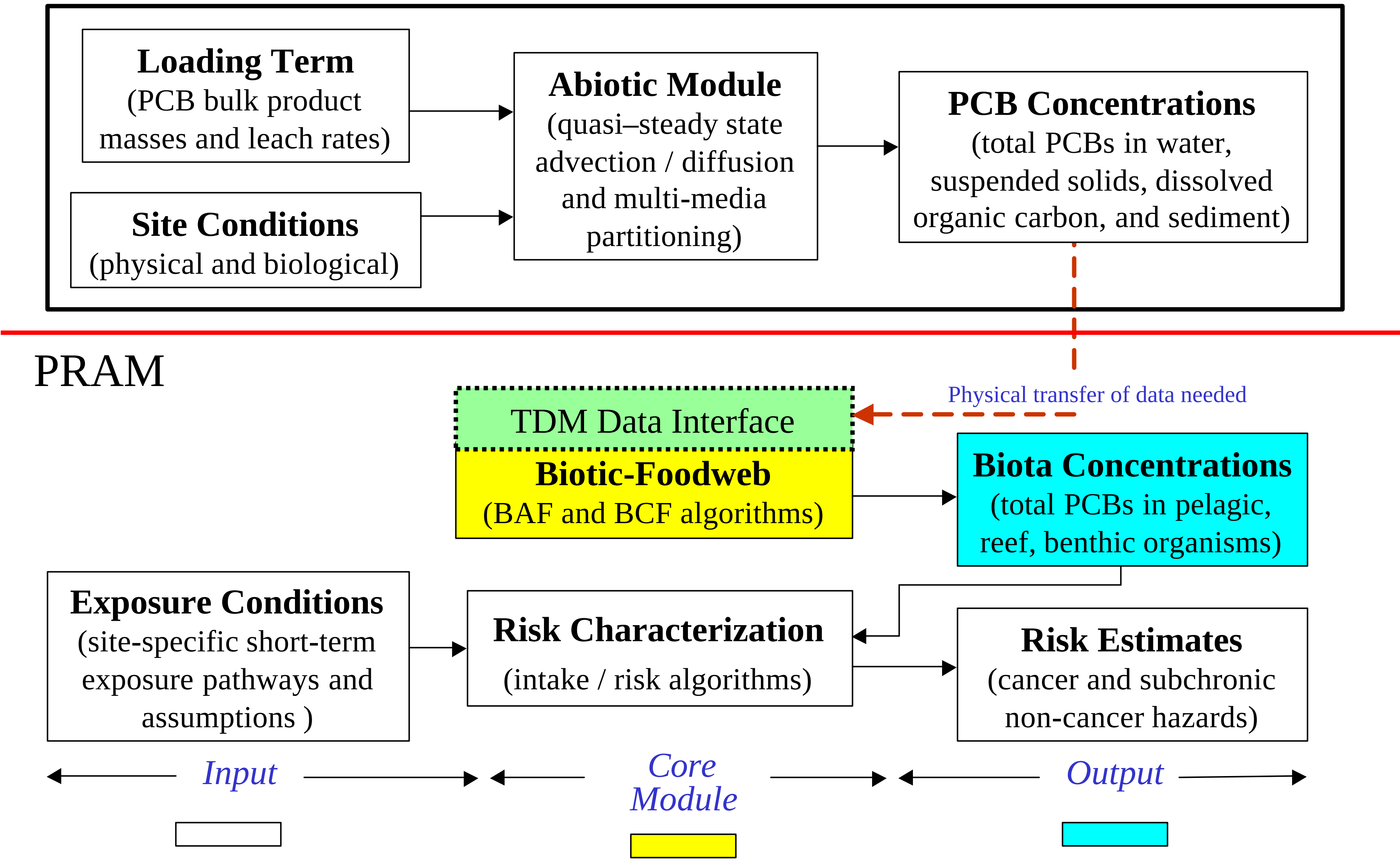


Figure 4-1

Short-term Human Health Risk Characterization with TDM

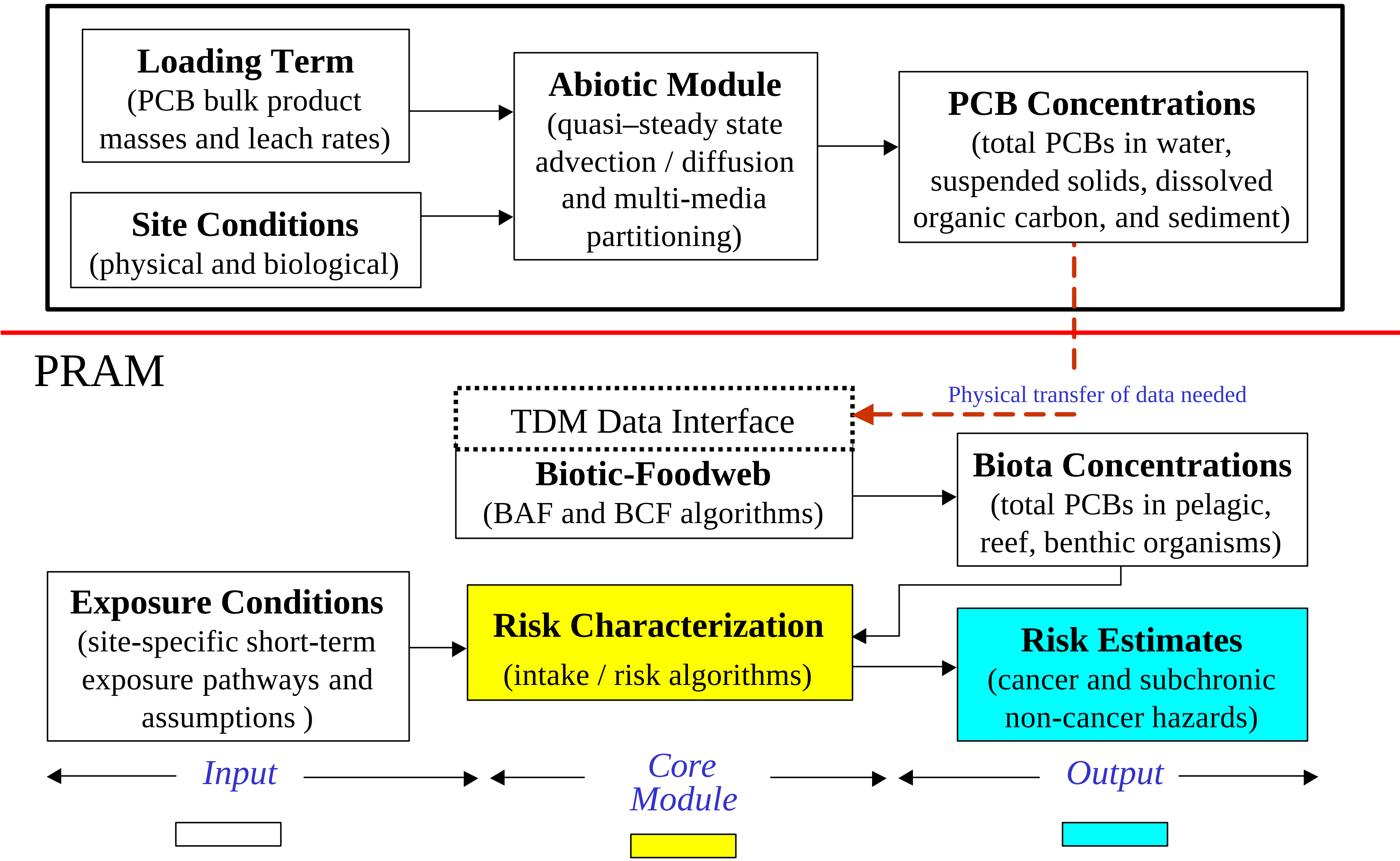


Figure 4-2
SCEM – Site Conceptual Exposure Model

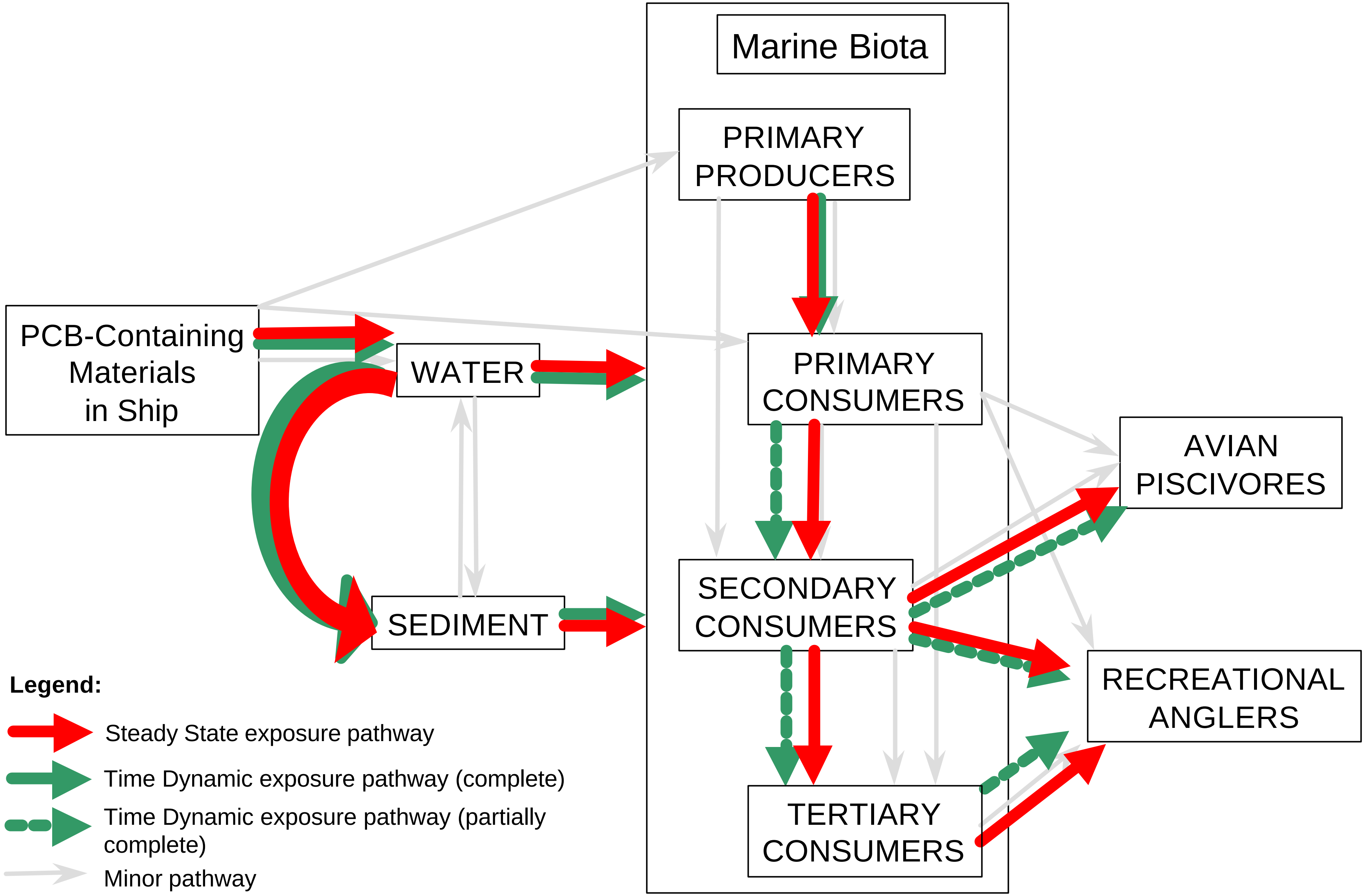


Figure 4-3

NOAA NO-DECOMPRESSION AIR TABLE

WARNING: EVEN STRICT COMPLIANCE WITH THESE CHARTS WILL NOT GUARANTEE AVOIDANCE OF DECOMPRESSION SICKNESS. CONSERVATIVE USAGE IS STRONGLY RECOMMENDED.

RNT RESIDUAL NITROGEN TIME
+**ABT** ACTUAL BOTTOM TIME
ESDT EQUIVALENT SINGLE DIVE TIME

(USE ESDT TO DETERMINE END-OF-DIVE LETTER GROUP)

CHART 1 - DIVE TIMES WITH END-OF-DIVE GROUP LETTER

00 MAXIMUM NO-STOP TIME

DEPTH MSW	FEET	A	B	C	D	E	F	G	H	I	J	K	L	M	N
12	40	5	15	25	30	40	50	70	80	100	110	130	150	170	200
15	50		10	15	25	30	40	50	60	70	80	90	100	120 5	160 21
18	60		10	15	20	25	30	40	50	55	60	70 2	80 7	100 14	
22	70		5	10	15	20	30	35	40	45	50	60 8	70 14	80 18	
25	80		5	10	15	20	25	30	35	40		50 10	60 17	70 23	
28	90		5	10	12	15	20	25	30		40 7		50 18	60 25	
31	100		5	7	10	15	20	22	25	30 3		40 15			
34	110			5	10	13	15	20	25 3		30 7				
37	120			5	10	12	15		20 2	25 6	30 14				
40	130			5	8	10	15 1		20 4		25 10				

CHART 2 - SURFACE INTERVAL TIME

GROUP	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A	12:00 0:10	12:00 3:21	12:00 4:50	12:00 5:49	12:00 6:35	12:00 7:06	12:00 7:36	12:00 8:00	12:00 8:22	12:00 8:51	12:00 8:59	12:00 9:13	12:00 9:29	12:00 9:44
B		3:20 0:10	4:49 1:40	5:48 2:39	6:34 3:25	7:05 3:58	7:35 4:26	7:59 4:50	8:21 5:13	8:50 5:41	8:58 5:49	9:12 6:03	9:28 6:19	9:43 6:33
C			1:39 0:10	2:38 1:10	3:24 1:58	3:57 2:29	4:25 2:59	4:49 3:21	5:12 3:44	5:40 4:03	5:48 4:20	6:02 4:36	6:18 4:50	6:32 5:04
D				1:09 0:10	1:57 0:55	2:28 1:30	2:58 2:00	3:20 2:24	3:43 2:45	4:02 3:05	4:19 3:22	4:35 3:37	4:49 3:53	5:03 4:05
E					0:54 0:10	1:29 0:46	1:59 1:16	2:23 1:42	2:44 2:03	3:04 2:21	3:21 2:39	3:36 2:54	3:52 3:09	4:04 3:23
F						0:45 0:10	1:15 0:41	1:41 1:07	2:02 1:30	2:20 1:48	2:38 2:04	2:53 2:20	3:08 2:35	3:22 2:48
G							0:40 0:10	1:06 0:37	1:29 1:00	1:47 1:20	2:03 1:36	2:19 1:50	2:34 2:06	2:47 2:19
H								0:36 0:10	0:59 0:34	1:19 0:55	1:35 1:12	1:49 1:26	2:05 1:36	2:18 1:54
I									0:33 0:10	0:54 0:32	1:11 0:50	1:25 1:05	1:35 1:19	1:53 1:31
J										0:31 0:10	0:49 0:29	1:04 0:46	1:18 1:00	1:30 1:12
K											0:28 0:10	0:45 0:27	0:59 0:43	1:11 0:55
L												0:26 0:10	0:42 0:26	0:54 0:40
M													0:25 0:10	0:39 0:25
N														0:24 0:10

CHART 3 - REPETITIVE DIVE TIME

msw	12	15	18	22	25	28	31	34	37	40	GROUP
fsw	40	50	60	70	80	90	100	110	120	130	Letter
	7 193	6 94	5 55	4 46	4 36	3 27	3 22	3 17	3 12	3 7	A
	17 183	13 87	11 49	9 41	8 32	7 23	7 18	6 14	6 9	6 4	B
	25 175	21 79	17 43	15 35	13 27	11 19	10 15	10 10	9 6	8 2	C
	37 163	29 71	24 36	20 30	18 22	16 14	14 11	13 7	12 3		D
	49 151	38 62	30 30	26 24	23 17	20 10	18 7	16 4			E
	61 139	47 53	36 24	31 19	28 12	24 6	22 3				F
	73 127	56 44	44 16	37 13	32 8	29 1					G
	87 113	66 34	52 8	43 7	38 2						H
	101 99	76 24									I
	116 84	87 13									J
	138 62	99 1									K
	161 39										L
	187 13										M
											N

00 RED NUMBERS (TOP) ARE RESIDUAL NITROGEN TIMES (RNT)
00 BLACK NUMBERS (BOTTOM) ARE ADJUSTED NO-STOP REPETITIVE DIVE TIMES. ACTUAL DIVE TIME SHOULD NOT EXCEED THIS NUMBER

COMPUTER PROGRAMMING CODE FOR THE TIME DYNAMIC MODEL (TDM)

```
-
program;
set c:\pcb\simul\finalprephomologs;

create c:\pcb\simul\bigfiles\cl5ship (keep pulse release cumday cummin shippcb conc tssc docc)(buffer=65535); order pulse release cumday cummin shippcb conc tssc docc;
create c:\pcb\simul\bigfiles\cl5bud (keep pulse release cumday cummin shipmass cumrel cumwater upcumwat cumsed cumtss upcumtss cumdoc upcumdoc cumloss1
cumloss2)(buffer=65535); order pulse release cumday cummin shipmass cumrel cumwater upcumwat cumsed cumtss upcumtss cumdoc upcumdoc cumloss1 cumloss2;
create c:\pcb\simul\bigfiles\cl5sed (keep pulse release cumday cummin bconc1-bconc200)(buffer=65535); order pulse release cumday cummin  bconc1-bconc200;
create c:\pcb\simul\bigfiles\cl5wat (keep pulse release cumday cummin conc1-conc200)(buffer=65535); order pulse release cumday cummin conc1-conc200;
create c:\pcb\simul\bigfiles\cl5upperwat (keep pulse release cumday cummin uconc1-uconc200)(buffer=65535); order pulse release cumday cummin uconc1-uconc200;
create c:\pcb\simul\bigfiles\cl5tss (keep pulse release cumday cummin tssc1-tssc200)(buffer=65535); order pulse release cumday cummin  tssc1-tssc200;
create c:\pcb\simul\bigfiles\cl5uppertss (keep pulse release cumday cummin utssc1-utssc200)(buffer=65535); order pulse release cumday cummin  utssc1-utssc200;
create c:\pcb\simul\bigfiles\cl5doc (keep pulse release cumday cummin docc1-docc200)(buffer=65535); order pulse release cumday cummin  docc1-docc200;
create c:\pcb\simul\bigfiles\cl5upperdoc (keep pulse release cumday cummin udocc1-udocc200)(buffer=65535); order pulse release cumday cummin  udocc1-udocc200;

array volume [200] vol(1-200);
array mass [200] mass(1-200);
array conc [200] conc(1-200);
array watfl[200] watfl(1-200);
array uvol [200] uvol(1-200);
array umass [200] umass(1-200);
array uconc [200] uconc(1-200);
array uwatfl[200] uwatf(1-200);

array bflux [200] bflx(1-200);
array bcum [200] bcum(1-200);
array bconc[200] bconc(1-200);
array bvol[200] bvol(1-200);
array bmax[200] bmax(1-200);
array area[200] area(1-200);

array tsscm[200] tsscm(1-200);
array tssc[200] tssc(1-200);
array tssvl[200] tssvl(1-200);
array tssfl[200] tssfl(1-200);
array utsscm[200] utsscm(1-200);
array utssc[200] utssc(1-200);
array utssvl[200] utssvl(1-200);
array utssfl[200] utssfl(1-200);


array doccm[200] doccm(1-200);
array docc[200] docc(1-200);
array docvl[200] docvl(1-200);
array docfl[200] docfl(1-200);
array udoccm[200] udoccm(1-200);
```

COMPUTER PROGRAMMING CODE FOR THE TIME DYNAMIC MODEL (TDM)

```
array udocc[200] udocc(1-200);
array udocvl[200] udocvl(1-200);
array udocfl[200] udocfl(1-200);

array pcbtot1[200] pcbtot1(1-200);
array flux[200] flux(1-200);
array abflx[200] abflx(1-200);
/**********************************************initialize variables ***********************************************************/
pi=3.1415928;
bins=200;

rate=0.0032;                /*accounts for 1 minute time step when 99% equilibrium reached in 24 hours */
pycnrate=1.0728e-5;           /* 1 minute time step whn  99% equilibrium across pycnocline in 64.7 days  (Kz=0.1 cm^2/sec)  */
shiprate=0.547;              /* fraction of equilibrium with 247 minute DOC and TSS in-ship residence time */

depth=64;
pycno=15;
height=depth-pycno;

volume=(pi/4)*270*36.5*6.91*1e6;        /* these are ship related; length width and height of ellipse */
tssvl=volume*1e-5;              /* internal to ship */
docvl=volume*6e-7;              /* internal to ship */
freedvol=(pi/4)*(270+0.3)*(36.5+0.3)*6.91*1e6;     /* volume that escapes (is free) from inside to outside ship each minute */
freedvol=freedvol-volume;
freedtss=freedvol*1e-5;
freeddoc=freedvol*6e-7;

if _n_=1 then begin;
 initmass=5e5;               /* place holder for calculating percentages later */
 start=1;
 pulse=0;
 cummin=0;
 cumrel=0;
 mass=0;                  /* I use non-indexed variables inside the ship, indexed outside. The index denotes the bin number */
 tsscm=0;
 doccm=0;
 cumloss1=0;
 cumloss2=0;
end;



if _n_=1 then do i=1 to bins;
   m=i*15;
   bigarea=(pi/4)*(270+(2*m))*(36.5+(2*m));      /* these calculated sequential external bin volumes */
   prearea=(pi/4)*(270+(2*(m-15)))*(36.5+(2*(m-15)));
```

```
     area=bigarea-prearea;
     area[i]=area;

     volume[i]=area[i]*height*1e6;
     mass[i]=0;
     conc[i]=mass[i]/volume[i];
     watfl[i]=0;
     uvol[i]=area[i]*pycno*1e6;
     umass[i]=0;
     uconc[i]=0;
     uwatfl[i]=0;

     bflux[i]=0;
     bcum[i]=0;
     bconc[i]=0;
     bvol=area*1e4*1.5*10;
     bvol[i]=bvol;
     bmax[i]=0;

     tsscm[i]=0;
     tssc[i]=0;
     tssvl[i]=volume[i]*1e-5;
     utsscm[i]=0;
     utssc[i]=0;
     utssvl[i]=uvol[i]*1e-5;


     docvl[i]=volume[i] *6e-7;
     docc[i]=0;
     doccm[i]=0;
     udocvl[i]=uvol[i] *6e-7;
     udocc[i]=0;
     udoccm[i]=0;
     pcbtot1[i]=0;
     flux[i]=0;
     abflx[i]=0;
 end;


/*******************************get release rate and period input data from Rob George ************************************************************/

release=cl5;
release=release/(24*60);
prevrel=lag1(release);
period=days*24*60;
```

```
koc=8.61e4;                          /* this is a literature value */

sedpart=0.01*koc;                    /* the 0.1 and 0.15 are fractions of organic carbon in sediment and tts; doc is 100% organic carbon */
tsspart=0.15*koc;
docpart=koc;


/***************************************************program start **********************************************************/
do min=1 to period;
   if min=1 then start=1;                          /* this is a flag to keep concentrations 0 until PCB cloud arrives in the bin */
   if min=1 and prevrel<>0 and prevrel<>. then start=0;
   if min=1 then pulse=pulse+1;
   cummin=cummin+1;
   cumday=cummin/1440;
   cumday=int(cumday);                               /* I round here for daily mean calculations, otherwise I ran into a MALLOC memory bug */
/**********************************************inside the boat; variables lack index values ********************/
   cumrel=cumrel+release;
   mass=mass+release;
   conc=mass/volume;
   tssc=tsscm/tssvl;
   docc=doccm/docvl;

   shippcb=mass+tsscm+doccm;                               /* total mass released inside the ship */

    watequi=shippcb/ (volume+(tssvl*koc*0.15)+(docvl*koc*1));      /* equilibrium distributions of total mass released in ship */
    tssequi=watequi*koc*0.15;
    docequi=watequi*koc*1.0;

     watfl=shiprate*(watequi-conc)*volume;                      /* flux necessary to reach equilibrium conditions, but limited by what's allowed after 247 minutes */
     tssfl=shiprate*(tssequi-tssc)*tssvl;
     docfl=shiprate*( docequi-docc)*docvl;

     flux=watfl+tssfl+docfl;
     abflx=abs(watfl)+abs(tssfl)+abs(docfl);

     if flux<0 then begin;                           /*if desorption too fast, slow it down */
         brake=(abflx+flux)/(abflx-flux);                 /* always the case */
         if watfl<0 then watfl=watfl*brake;                /* without this brake, water desorbs ~12% more Cl5 mass than can be adsorbed */
         if tssfl<0 then tssfl=tssfl*brake;
         if docfl<0 then docfl=docfl*brake;
    end;

    if flux>0 then begin;                            /*if adsorption too fast, slow it down - never seen to occur */
         brake=(abflx-flux)/(abflx+flux);
         if watfl>0 then watfl=watfl*brake;
         if tssfl>0 then tssfl=tssfl*brake;
```

```
      if docfl>0 then docfl=docfl*brake;
   end;

   mass=mass+watfl;                        /* calculate the new mass distribution and concentrations */
   conc=mass/volume;

   tsscm=tsscm+tssfl;
   tssc=tsscm/tssvl;

   doccm=doccm+docfl;
   docc=doccm/docvl;
/*********************** what leaves the ship at 0.15 m/min in water tss and doc ****************************/
   freedpcb=(conc*freedvol)+(tssc*freedtss)+(docc*freeddoc);   /*total pcbs freed from ship */

   mass=mass-(conc*freedvol);
   conc=mass/volume;

   tsscm=tsscm-(tssc*freedtss);
   tssc=tsscm/tssvl;

   doccm=doccm-(docc*freeddoc);
   docc=doccm/docvl;

/************************************************first bin ************************************************************/
   do i=1 to bins;
      m=i*15;
      if i=1 then begin;
      uconc[i]=0;
      udocc[i]=0;
      utssc[i]=0;
/************************************************ship release  and dilution   **************************************/
         mass[i]=conc*freedvol;
         conc[i]=mass[i]/volume[i];

         tsscm[i]=tssc*freedtss;
         tssc[i]=tsscm[i]/tssvl[i];

         doccm[i]=docc*freeddoc;
         docc[i]=doccm[i]/docvl[i];
/*******************determine PCB mass in bin, above nd below pycnocline *****************************************/

mass[i]=conc[i]*volume[i];
umass[i]=uconc[i]*uvol[i];
tsscm[i]=tssc[i]*tssvl[i];
doccm[i]=docc[i]*docvl[i];
udoccm[i]=udocc[i]*udocvl[i];
```

```
utsscm[i]=utssc[i]*utssvl[i];
bcum[i]=bconc[i]*bvol[i];

pcbtot1[i]=mass[i]+bcum[i]+tsscm[i]+doccm[i]+umass[i]+utsscm[i]+udoccm[i];  /*this is the starting mass to be redistributed */

r0=0.57*bmax[i];                                    /* these are Di Toro and Horzempa's (1982) retention terms */
px=(1/2.3)*koc*0.01;

/**************************************determine equilibrium concentrations **************************************/


if bconc[i]>=bmax[i] then begin;
   watequi=pcbtot1[i]/ ((volume[i]+uvol[i])+bvol[i]*koc*0.01+((tssvl[i]+utssvl[i])*koc*0.15)+((docvl[i]+udocvl[i])*koc*1));
    sedequi=watequi*koc*0.01;
end;

if bconc[i]<bmax[i] then begin;
   watequi=(pcbtot1[i]-r0*bvol[i])/ ((volume[i]+uvol[i])+bvol[i]*px+((tssvl[i]+utssvl[i])*koc*0.15)+((docvl[i]+udocvl[i])*koc*1));
    sedequi=r0+watequi*px;
end;

tssequi=watequi*koc*0.15;
docequi=watequi*koc*1.0;
upwateq=watequi;
uptsseq=watequi*koc*0.15;
updoceq=watequi*koc*1.0;

/***********************determine fluxes occurring in 1 minute ****************************************************/


  watfl[i]=rate*(watequi-conc[i])*volume[i];
  bflux[i]=rate*(sedequi-bconc[i])*bvol[i];
  tssfl[i]=rate*(tssequi-tssc[i])*tssvl[i];
  docfl[i]=rate*(docequi-docc[i])*docvl[i];
  uwatfl[i]=pycnrate*(upwateq-uconc[i])*uvol[i];
  utssfl[i]=pycnrate*(uptsseq-utssc[i])*utssvl[i];
  udocfl[i]=pycnrate*(updoceq-udocc[i])*udocvl[i];

flux[i]=watfl[i]+bflux[i]+tssfl[i]+docfl[i]+uwatfl[i]+utssfl[i]+udocfl[i];
abflx[i]=abs(watfl[i])+abs(bflux[i])+abs(tssfl[i])+abs(docfl[i])+abs(uwatfl[i])+abs(utssfl[i])+abs(udocfl[i]);



if flux[i]<0 then begin;                              /*if desorption too fast, slow it down */
    brake=(abflx[i]+flux[i])/(abflx[i]-flux[i]);
    if watfl[i]<0 then watfl[i]=watfl[i]*brake;
```

```
    if bflux[i]<0 then bflux[i]=bflux[i]*brake;             /* flux (net flux) is <>0 except when there is no loading */
    if tssfl[i]<0 then tssfl[i]=tssfl[i]*brake;
    if docfl[i]<0 then docfl[i]=docfl[i]*brake;
    if uwatfl[i]<0 then uwatfl[i]=uwatfl[i]*brake;
    if utssfl[i]<0 then utssfl[i]=utssfl[i]*brake;
    if udocfl[i]<0 then udocfl[i]=udocfl[i]*brake;
end;

if flux[i]>0 then begin;                              /*if adsorption too fast, slow it down - not observed  */
    brake=(abflx[i]-flux[i])/(abflx[i]+flux[i]);
    if watfl[i]>0 then watfl[i]=watfl[i]*brake;
    if bflux[i]>0 then bflux[i]=bflux[i]*brake;
    if tssfl[i]>0 then tssfl[i]=tssfl[i]*brake;
    if docfl[i]>0 then docfl[i]=docfl[i]*brake;
    if uwatfl[i]>0 then uwatfl[i]=uwatfl[i]*brake;
    if utssfl[i]>0 then utssfl[i]=utssfl[i]*brake;
    if udocfl[i]>0 then udocfl[i]=udocfl[i]*brake;
end;

  mass[i]=mass[i]+watfl[i];                           /* calculate the new mass distribution and concentrations */
  conc[i]=mass[i]/volume[i];

  bcum[i]=bcum[i]+bflux[i];
  bconc[i]=bcum[i]/bvol[i];
  if bconc[i]>bmax[i] then bmax[i]=bconc[i];

  tsscm[i]=tsscm[i]+tssfl[i];
  tssc[i]=tsscm[i]/tssvl[i];

  doccm[i]=doccm[i]+docfl[i];
  docc[i]=doccm[i]/docvl[i];

  umass[i]=umass[i]+uwatfl[i];
  uconc[i]=umass[i]/uvol[i];

  utsscm[i]=utsscm[i]+utssfl[i];
  utssc[i]=utsscm[i]/utssvl[i];

  udoccm[i]=udoccm[i]+udocfl[i];
  udocc[i]=udoccm[i]/udocvl[i];

end;                                                   /* end of bins=1 loop */
/***************************************************** all the other bins *************************************************************/
/*******************determine PCB mass in bin, above and below pycnocline ******************************************/
else begin;
```

```
        if i>min and start=1 then mass[i]=0;  else mass[i]=mass[i-1]; conc[i]=mass[i]/volume[i];
        if i>min and start=1 then umass[i]=0;  else umass[i]=umass[i-1]; uconc[i]=umass[i]/uvol[i];
        if i>min and start=1 then doccm[i]=0; else doccm[i]=doccm[i-1] ; docc[i]=doccm[i]/docvl[i];
        if i>min and start=1 then tsscm[i]=0; else tsscm[i]=tsscm[i-1] ; tssc[i]=tsscm[i]/tssvl[i];
        if i>min and start=1 then udoccm[i]=0; else udoccm[i]=udoccm[i-1] ;  udocc[i]=udoccm[i]/udocvl[i];
        if i>min and start=1 then utsscm[i]=0; else utsscm[i]=utsscm[i-1] ; utssc[i]=utsscm[i]/utssvl[i];

r0=0.57*bmax[i];
px=(1/2.3)*koc*0.01;

pcbtot1[i]=mass[i]+bcum[i]+tsscm[i]+doccm[i]+umass[i]+utsscm[i]+udoccm[i];

/****************************************determine equilibrium concentrations ****************************************/

if bconc[i]>=bmax[i] then begin;
   watequi=pcbtot1[i]/ ((volume[i]+uvol[i])+bvol[i]*koc*0.01+((tssvl[i]+utssvl[i])*koc*0.15)+((docvl[i]+udocvl[i])*koc*1));
   sedequi=watequi*koc*0.01;
end;

if bconc[i]<bmax[i] then begin;
   watequi=(pcbtot1[i] - r0*bvol[i]) / ((volume[i]+uvol[i])+bvol[i]*px+((tssvl[i]+utssvl[i])*koc*0.15)+((docvl[i]+udocvl[i])*koc*1));
   sedequi=r0+watequi*px;
end;

tssequi=watequi*koc*0.15;
docequi=watequi*koc*1.0;
upwateq=watequi;
uptsseq=watequi*koc*0.15;
updoceq=watequi*koc*1.0;

/***********************determine fluxes occurring in 1 minute ****************************************************/

 watfl[i]=rate*(watequi-conc[i])*volume[i];
 bflux[i]=rate*(sedequi-bconc[i])*bvol[i];
 tssfl[i]=rate*(tssequi-tssc[i])*tssvl[i];
 docfl[i]=rate*(docequi-docc[i])*docvl[i];
 uwatfl[i]=pycnrate*(upwateq-uconc[i])*uvol[i];
 utssfl[i]=pycnrate*(uptsseq-utssc[i])*utssvl[i];
 udocfl[i]=pycnrate*(updoceq-udocc[i])*udocvl[i];

flux[i]=watfl[i]+bflux[i]+tssfl[i]+docfl[i]+uwatfl[i]+utssfl[i]+udocfl[i];
abflx[i]=abs(watfl[i])+abs(bflux[i])+abs(tssfl[i])+abs(docfl[i])+abs(uwatfl[i])+abs(utssfl[i])+abs(udocfl[i]);


if flux[i]<0 then begin;                    /*if desorption too fast, slow it down */
   brake=(abflx[i]+flux[i])/(abflx[i]-flux[i]);
```

```
    if watfl[i]<0 then watfl[i]=watfl[i]*brake;
    if bflux[i]<0 then bflux[i]=bflux[i]*brake;
    if tssfl[i]<0 then tssfl[i]=tssfl[i]*brake;
    if docfl[i]<0 then docfl[i]=docfl[i]*brake;
    if uwatfl[i]<0 then uwatfl[i]=uwatfl[i]*brake;
    if utssfl[i]<0 then utssfl[i]=utssfl[i]*brake;
    if udocfl[i]<0 then udocfl[i]=udocfl[i]*brake;
end;

if flux[i]>0 then begin;                    /*if adsorption too fast, slow it down */
    brake=(abflx[i]-flux[i])/(abflx[i]+flux[i]);
    if watfl[i]>0 then watfl[i]=watfl[i]*brake;
    if bflux[i]>0 then bflux[i]=bflux[i]*brake;
    if tssfl[i]>0 then tssfl[i]=tssfl[i]*brake;
    if docfl[i]>0 then docfl[i]=docfl[i]*brake;
    if uwatfl[i]>0 then uwatfl[i]=uwatfl[i]*brake;
    if utssfl[i]>0 then utssfl[i]=utssfl[i]*brake;
    if udocfl[i]>0 then udocfl[i]=udocfl[i]*brake;
end;

  mass[i]=mass[i]+watfl[i];
  conc[i]=mass[i]/volume[i];

  bcum[i]=bcum[i]+bflux[i];
  bconc[i]=bcum[i]/bvol[i];
  if bconc[i]>bmax[i] then bmax[i]=bconc[i];

  tsscm[i]=tsscm[i]+tssfl[i];
  tssc[i]=tsscm[i]/tssvl[i];

  doccm[i]=doccm[i]+docfl[i];
  docc[i]=doccm[i]/docvl[i];

  umass[i]=umass[i]+uwatfl[i];
  uconc[i]=umass[i]/uvol[i];

  utsscm[i]=utsscm[i]+utssfl[i];
  utssc[i]=utsscm[i]/utssvl[i];

  udoccm[i]=udoccm[i]+udocfl[i];
  udocc[i]=udoccm[i]/udocvl[i];

 end;                                         /* end of the bins loop, out at 3 km */
/***************************************************************budget stuff:  pickup at the edge of the world for cumloss 2  *******************/
      if i=bins then begin;
            watloss=mass[i];
```

```
              tssloss=tssc[i]*tssvl[i];
              docloss=docc[i]*docvl[i];
              uwatloss=umass[i];
              utssloss=utssc[i]*utssvl[i];
              udocloss=udocc[i]*udocvl[i];
          end;
   exitloss=watloss+tssloss+docloss+uwatloss+utssloss+udocloss;  /* this will leave the model in the next iteration */
   end;
/************************************************************more budget stuff, pickup load inside model domain ***************************/
   cumwater=0;
   cumsed=0;
   cumtss=0;
   cumdoc=0;
   upcumwat=0;
   upcumtss=0;
   upcumdoc=0;
   do i=1 to bins;
       cumwater=cumwater+mass[i];
       upcumwat=upcumwat+umass[i];
       cumsed=cumsed+bcum[i];
       upcumtss=upcumtss+utsscm[i];
       cumtss=cumtss+tsscm[i];
       cumdoc=cumdoc+doccm[i];
       upcumdoc=upcumdoc+udoccm[i];
   end;
   shipmass=initmass-cumrel;
   modelmass=mass+tsscm+doccm+
             cumwater+cumsed+cumtss+cumdoc+upcumwat+upcumtss+upcumdoc;  /* PCB mass in model domain */
   cumloss1=cumrel-modelmass;                                /* one calculation of what's leaving */
   cumloss2=cumloss2+exitloss;                               /* the other calculation of what's leaving - hopefully they're pretty close */
  output;
end;
run;

/************* calculate daily means and export for graphics. Bin 63 was a maximum range for tss in an earlier model, I keep it for reference now****/

unistat;
set c:\pcb\simul\bigfiles\cl5ship(buffer=65535);
var shippcb conc tssc docc;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5ship mean=shippcb conc tssc docc;
run;


compute;
in=c:\pcb\simul\bigfiles\cl5sed.dbs
```

```
   out=c:\pcb\simul\bigfiles\cl5sed.ascii2(buffer=65535);
order pulse release cumday cummin bconc1 bconc63;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5sed(buffer=65535);
var bconc1-bconc200;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5sed mean=bconc1-bconc200;
run;


compute;
in=c:\pcb\simul\bigfiles\cl5wat.dbs
   out=c:\pcb\simul\bigfiles\cl5wat.ascii2(buffer=65535);
order pulse release cumday cummin conc1 conc63;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5wat(buffer=65535);
var conc1-conc200;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5wat mean=conc1-conc200;
run;

compute;
in=c:\pcb\simul\bigfiles\cl5upperwat.dbs
   out=c:\pcb\simul\bigfiles\cl5upperwat.ascii2(buffer=65535);
order pulse release cumday cummin uconc1 uconc63;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5upperwat(buffer=65535);
var uconc1-uconc200;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5uwat mean=uconc1-uconc200;
run;

compute;
in=c:\pcb\simul\bigfiles\cl5tss.dbs
   out=c:\pcb\simul\bigfiles\cl5tss.ascii2(buffer=65535);
order pulse release cumday cummin tssc1 tssc63;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5tss(buffer=65535);
```

```
var tssc1-tssc200;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5tss mean=tssc1-tssc200;
run;


compute;
in=c:\pcb\simul\bigfiles\cl5uppertss.dbs
   out=c:\pcb\simul\bigfiles\cl5uppertss.ascii2(buffer=65535);
order pulse release cumday cummin utssc1 utssc63;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5uppertss(buffer=65535);
var utssc1-utssc200;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5utss mean=utssc1-utssc200;
run;

compute;
in=c:\pcb\simul\bigfiles\cl5doc.dbs
   out=c:\pcb\simul\bigfiles\cl5doc.ascii2(buffer=65535);
order pulse release cumday cummin docc1 docc63;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5doc(buffer=65535);
var docc1-docc200;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5doc mean=docc1-docc200;
run;


compute;
in=c:\pcb\simul\bigfiles\cl5upperdoc.dbs
   out=c:\pcb\simul\bigfiles\cl5upperdoc.ascii2(buffer=65535);
order pulse release cumday cummin udocc1 udocc63;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5upperdoc(buffer=65535);
var udocc1-udocc200;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5udoc mean=udocc1-udocc200;
run;
```

```
compute;
in=c:\pcb\simul\bigfiles\cl5bud.dbs
   out=c:\pcb\simul\bigfiles\cl5budget.ascii2(buffer=65535);
order pulse release cumday cummin shipmass cumrel cumwater upcumwat cumsed cumtss upcumtss cumdoc upcumdoc cumloss1 cumloss2;
run;

unistat;
set c:\pcb\simul\bigfiles\cl5bud(buffer=65535);
var shipmass cumrel cumwater upcumwat cumsed cumtss upcumtss cumdoc upcumdoc cumloss1 cumloss2;
class cumday _lowest_;
output c:\pcb\simul\daymean\cl5bud mean=shipmass cumrel cumwater upcumwat cumsed cumtss upcumtss cumdoc upcumdoc cumloss1 cumloss2;
run;


exit;
```

Figure B 1 - Total PCB in Water Below Pycnocline

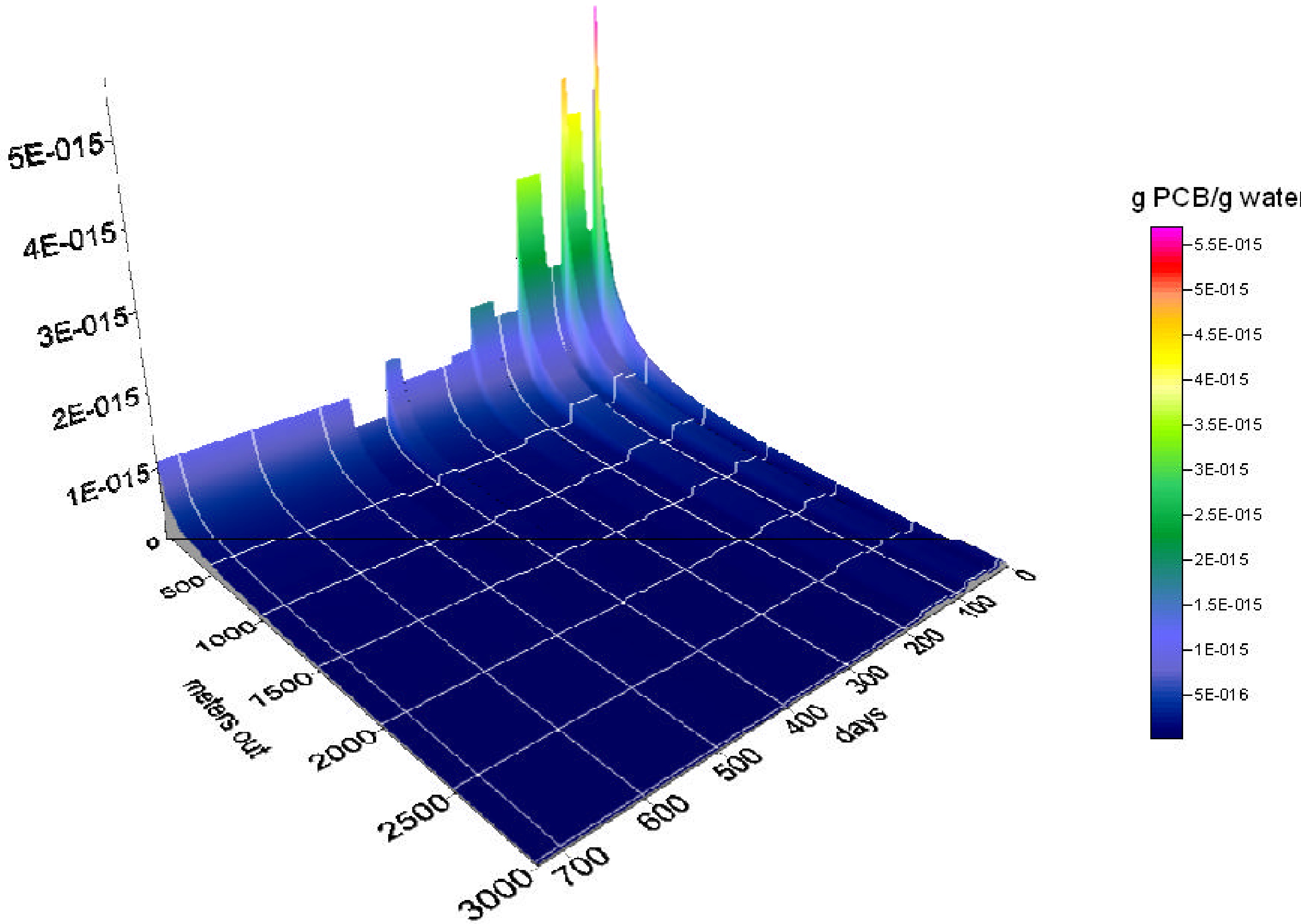


Figure B 2 - Monochlorobiphenyl in Water below Pycnocline

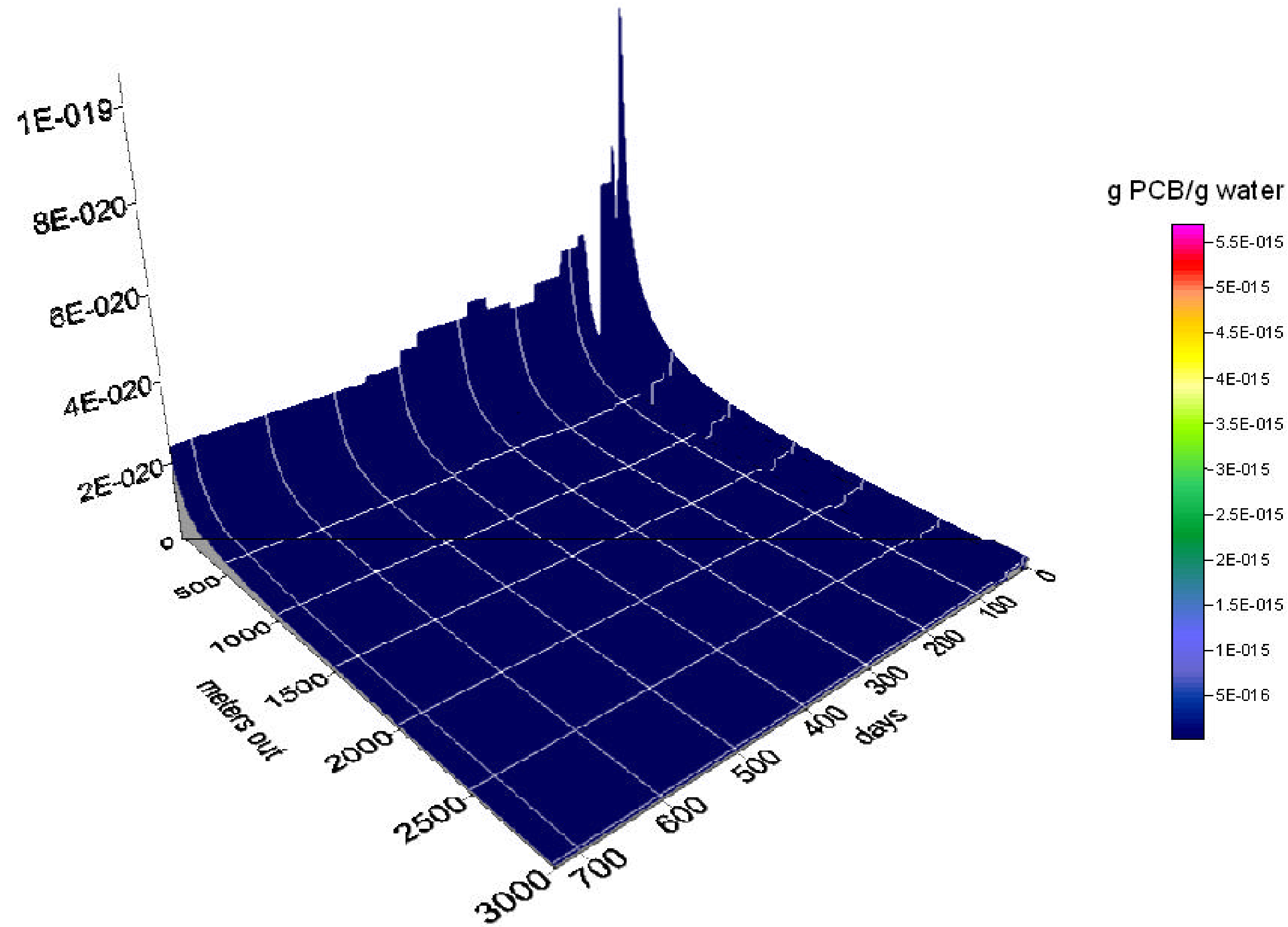


Figure B 3 - Dichlorobiphenyl in Water below Pycnocline

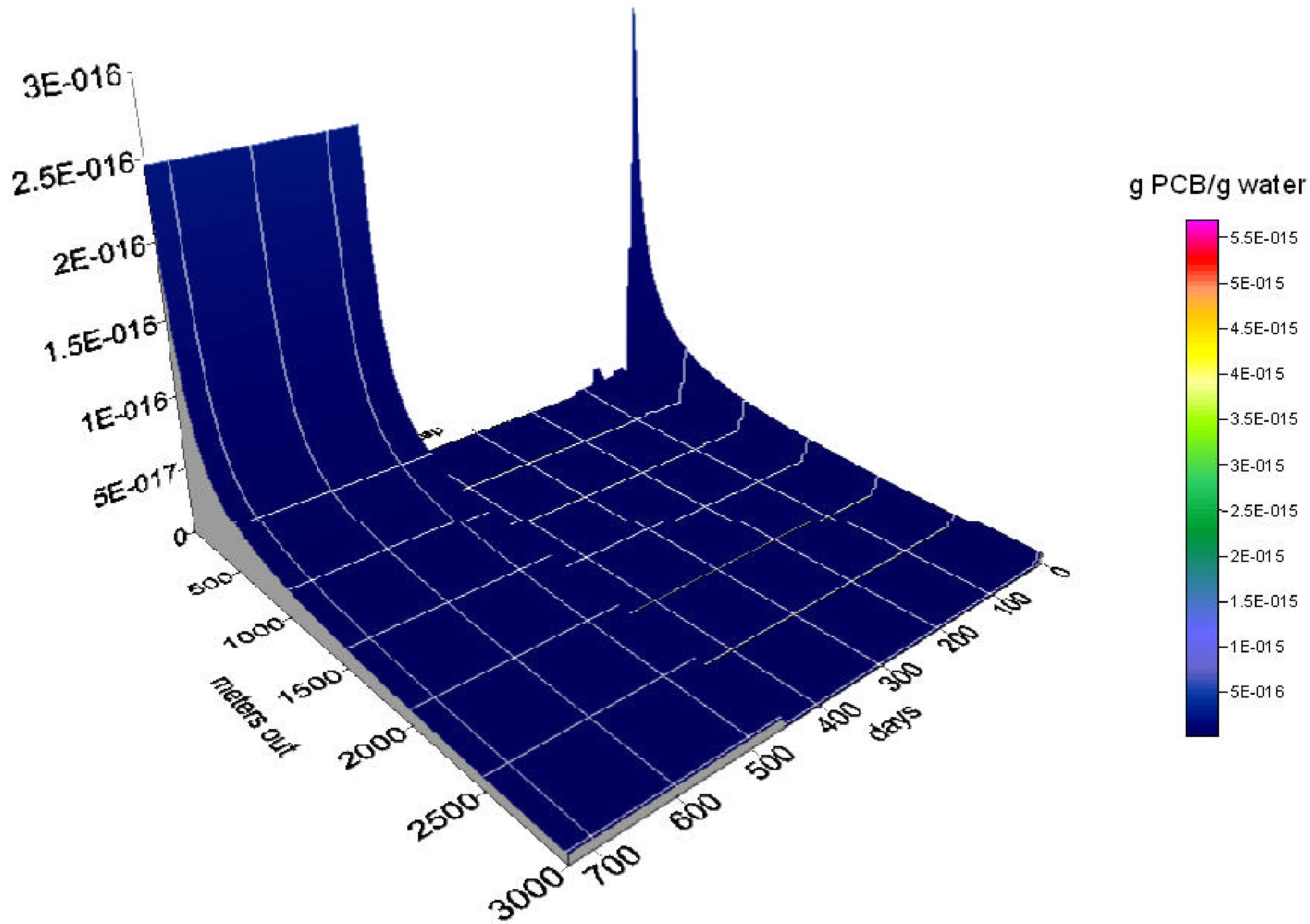


Figure B 4 - Trichlorobiphenyl in Water below Pycnocline

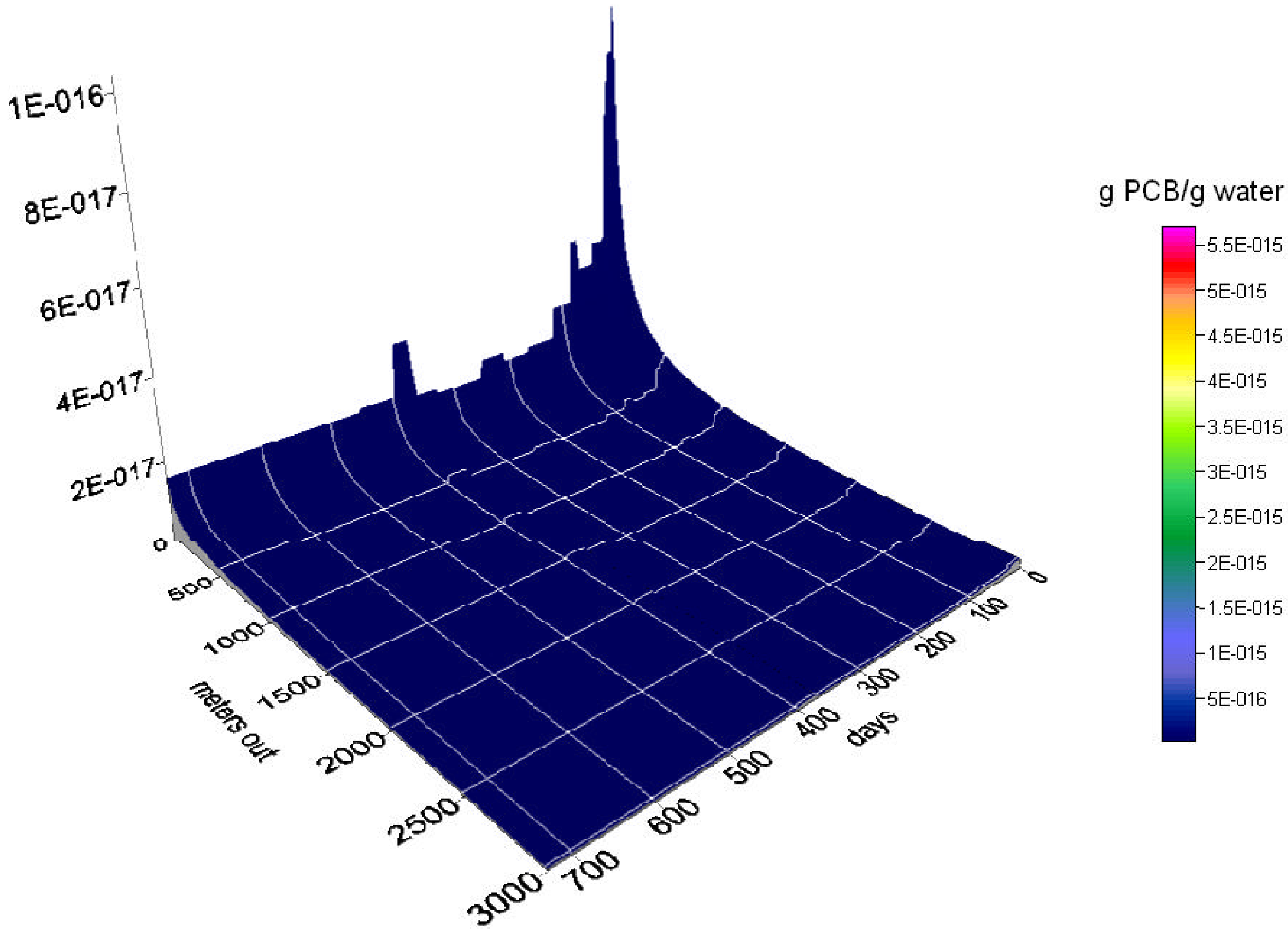


Figure B 5 - Tetrachlorobiphenyl in Water below Pycnocline

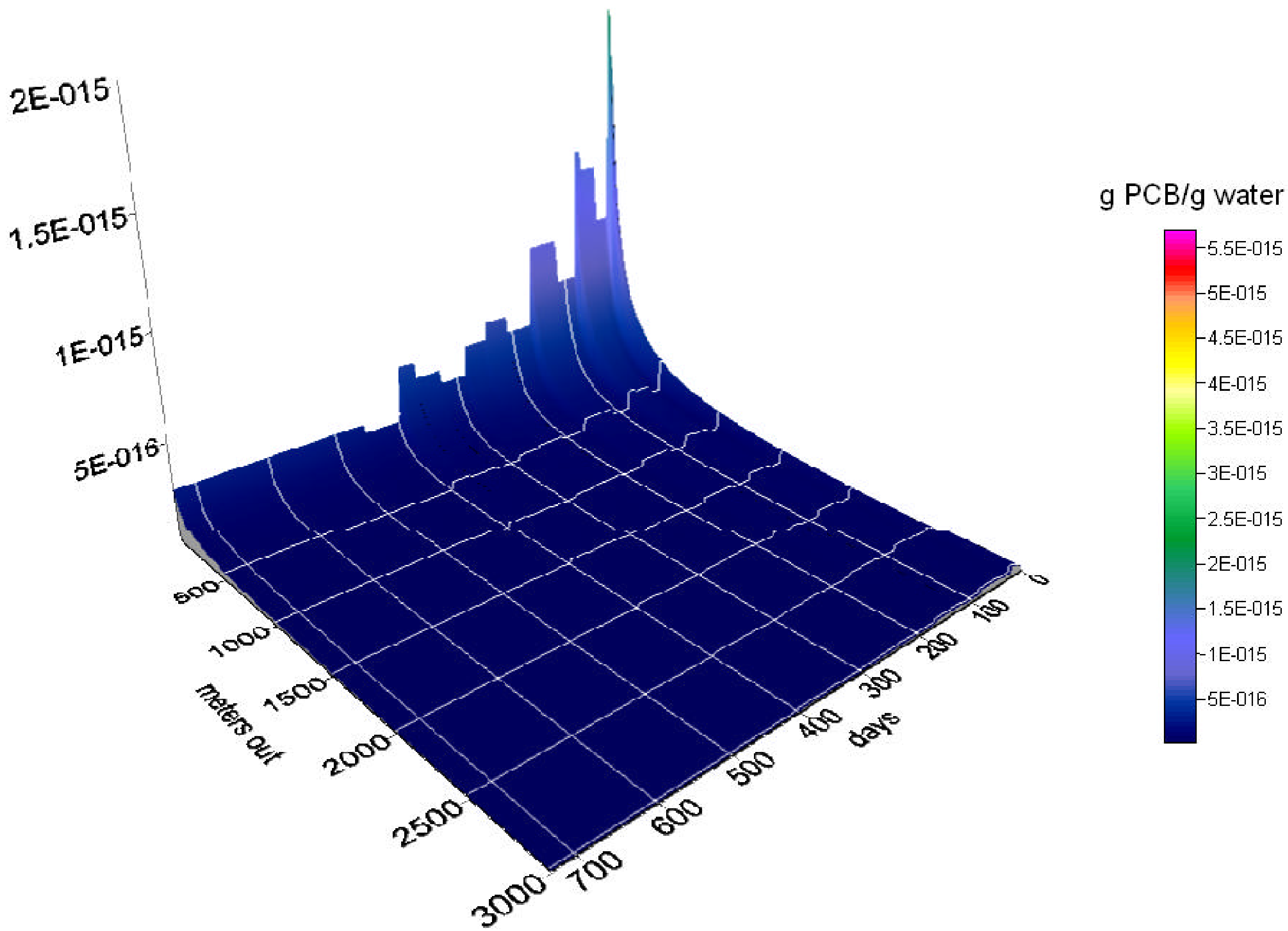


Figure B 6 - Pentachlorobiphenyl in Water below Pycnocline

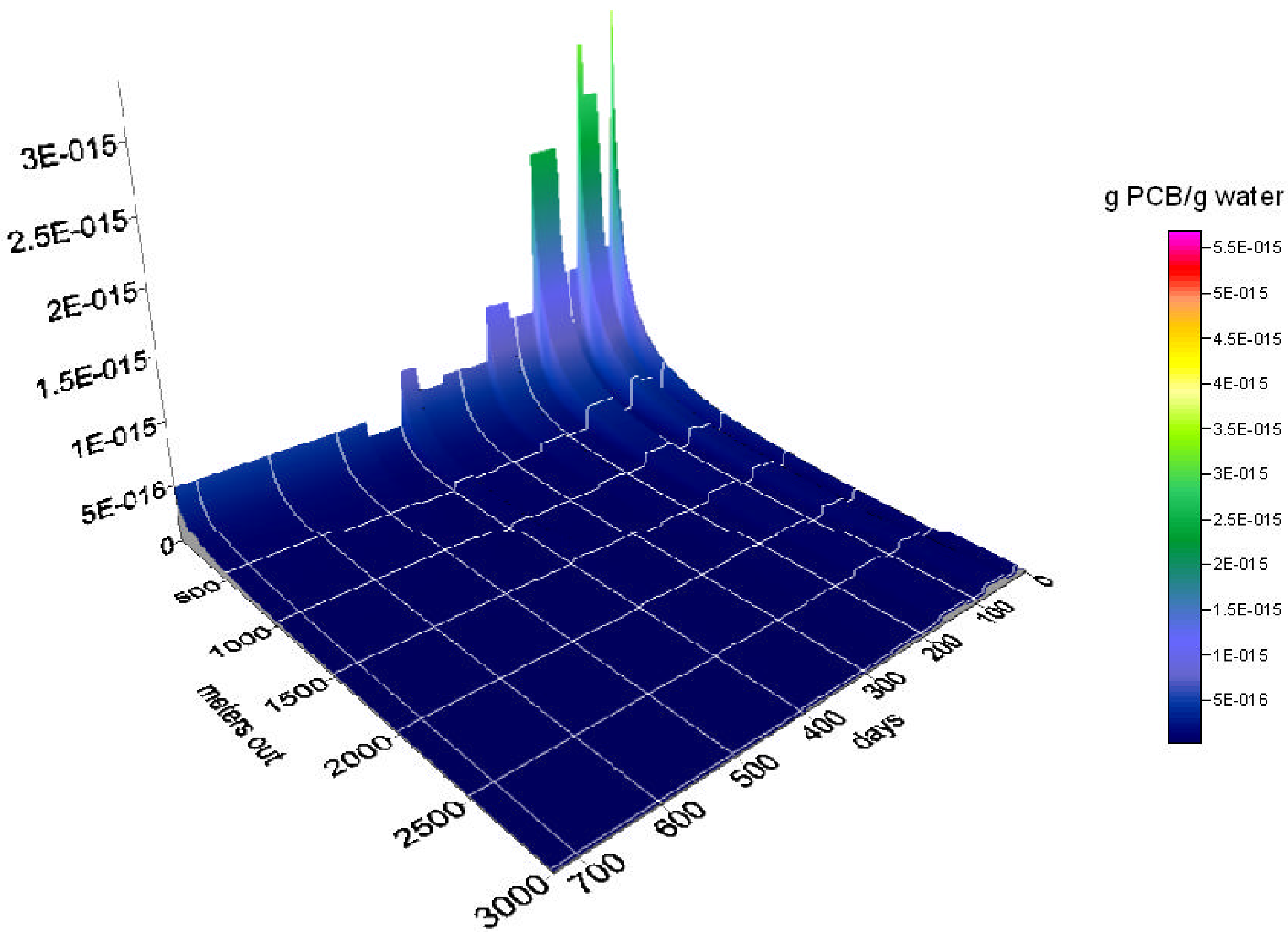


Figure B 7 - Hexachlorobiphenyl in Water below Pycnocline

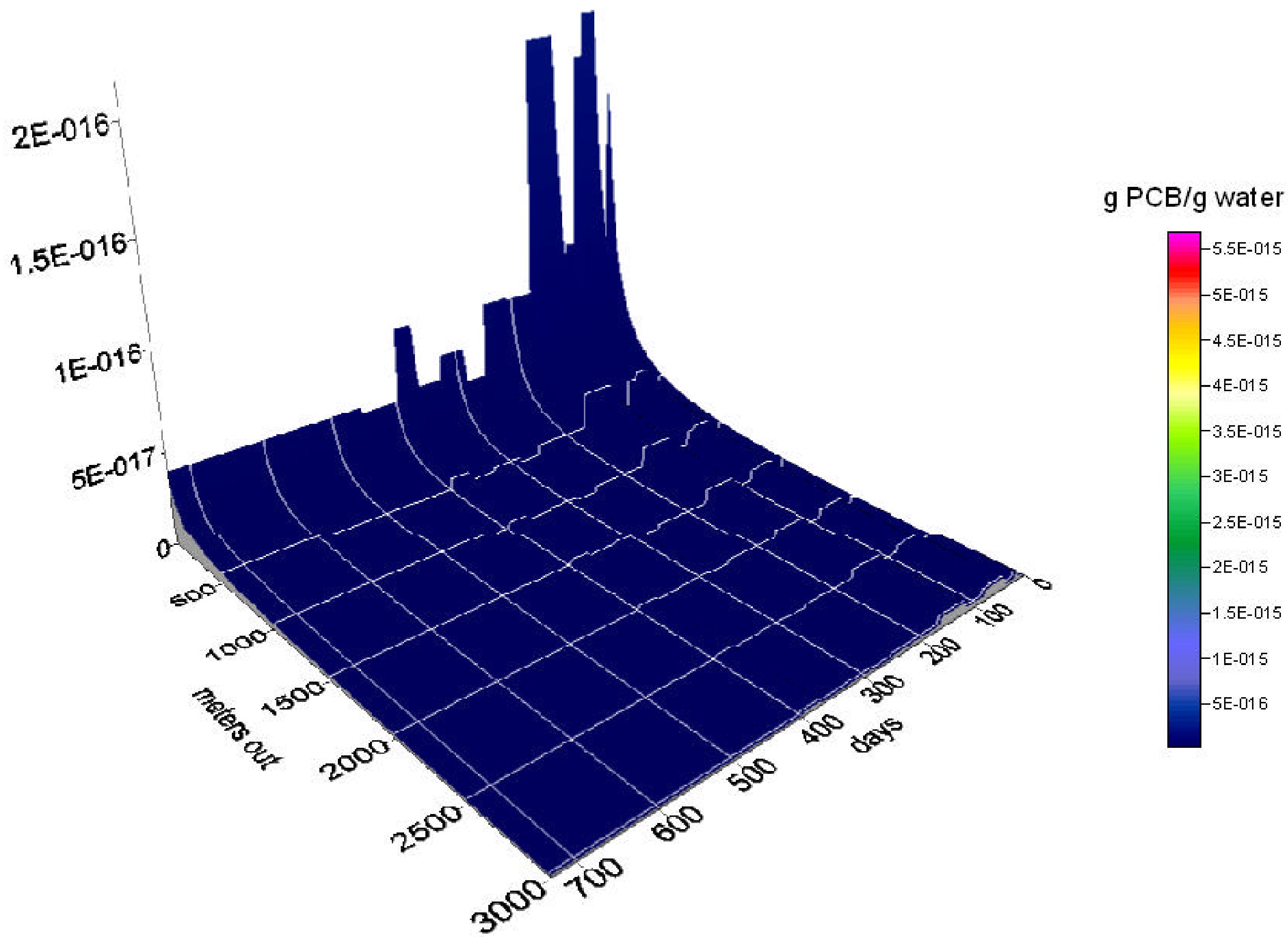


Figure B 8 - Heptachlorobiphenyl in Water below Pycnocline

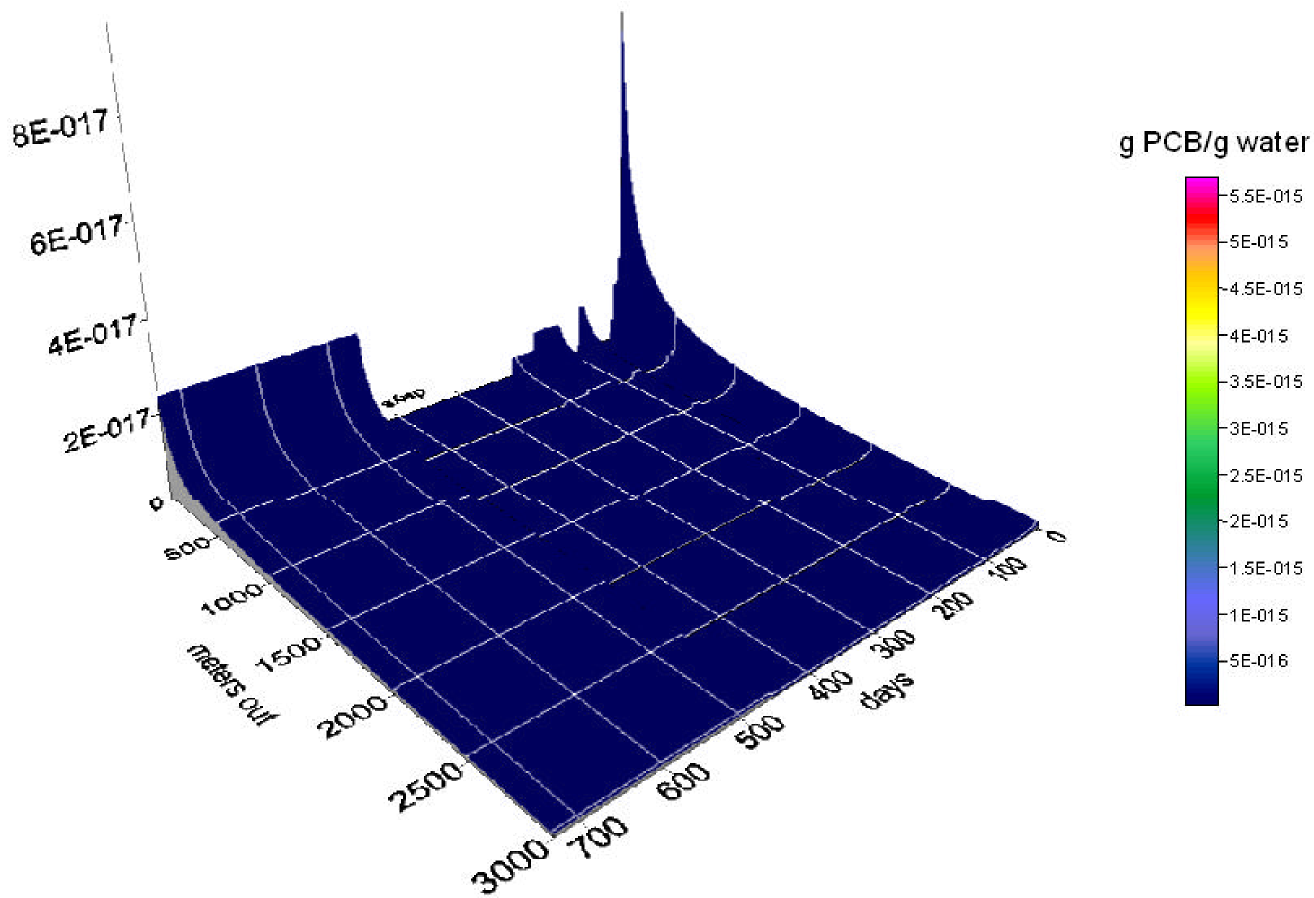


Figure B 9 - Nonachlorobiphenyl in Water below Pycnocline

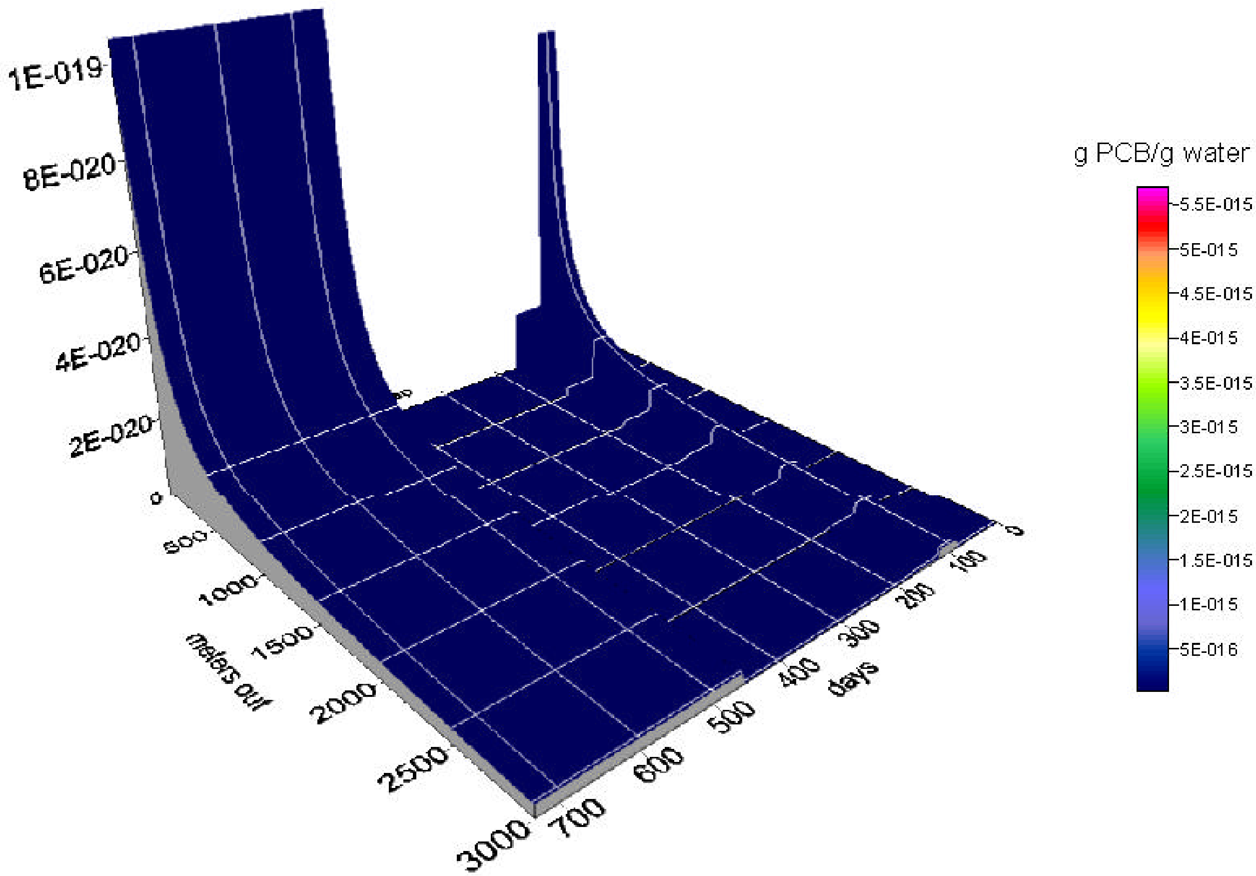
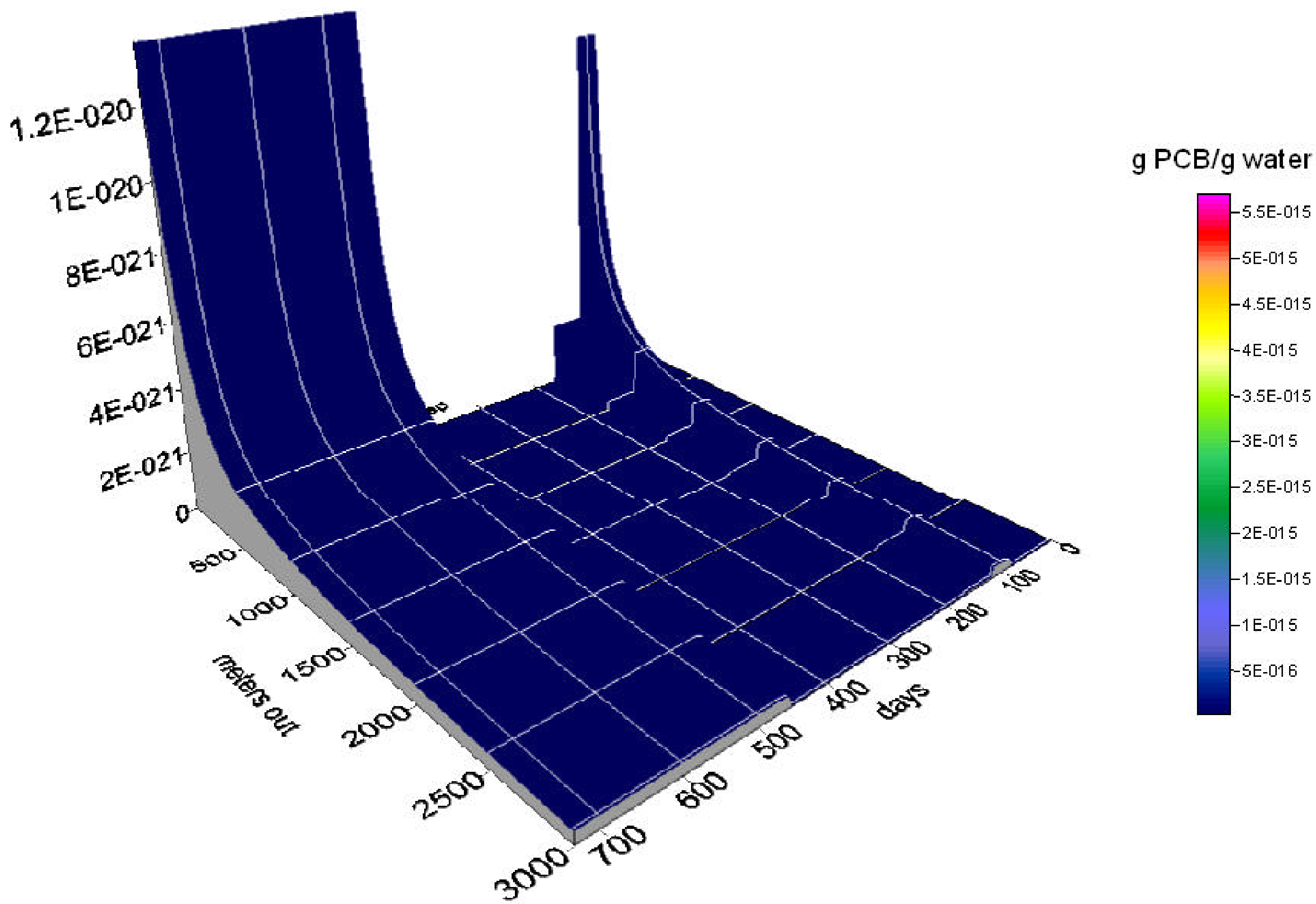


Figure B 10 - Decachlorobiphenyl in Water below Pycnocline



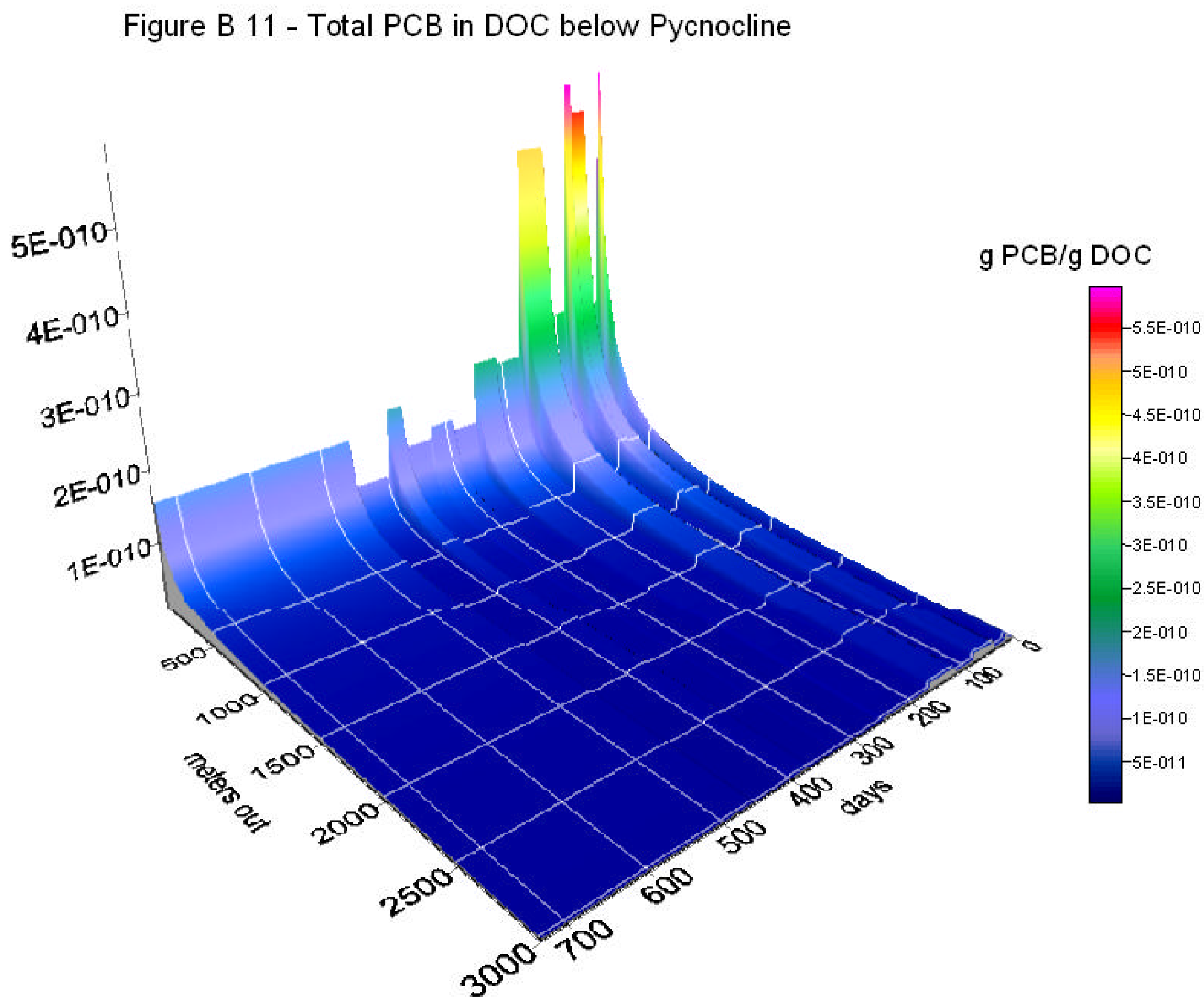


Figure B 11 - Total PCB in DOC below Pycnocline
5E-010
4E-010
3E-010
2E-010
1E-010
500
1000
1500
2000
2500
3000
meters out
0
100
200
300
400
500
600
700
days
g PCB/g DOC
5.5E-010
5E-010
4.5E-010
4E-010
3.5E-010
3E-010
2.5E-010
2E-010
1.5E-010
1E-010
5E-011

Figure B 12 – Monochlorobiphenyl in DOC below Pycnocline

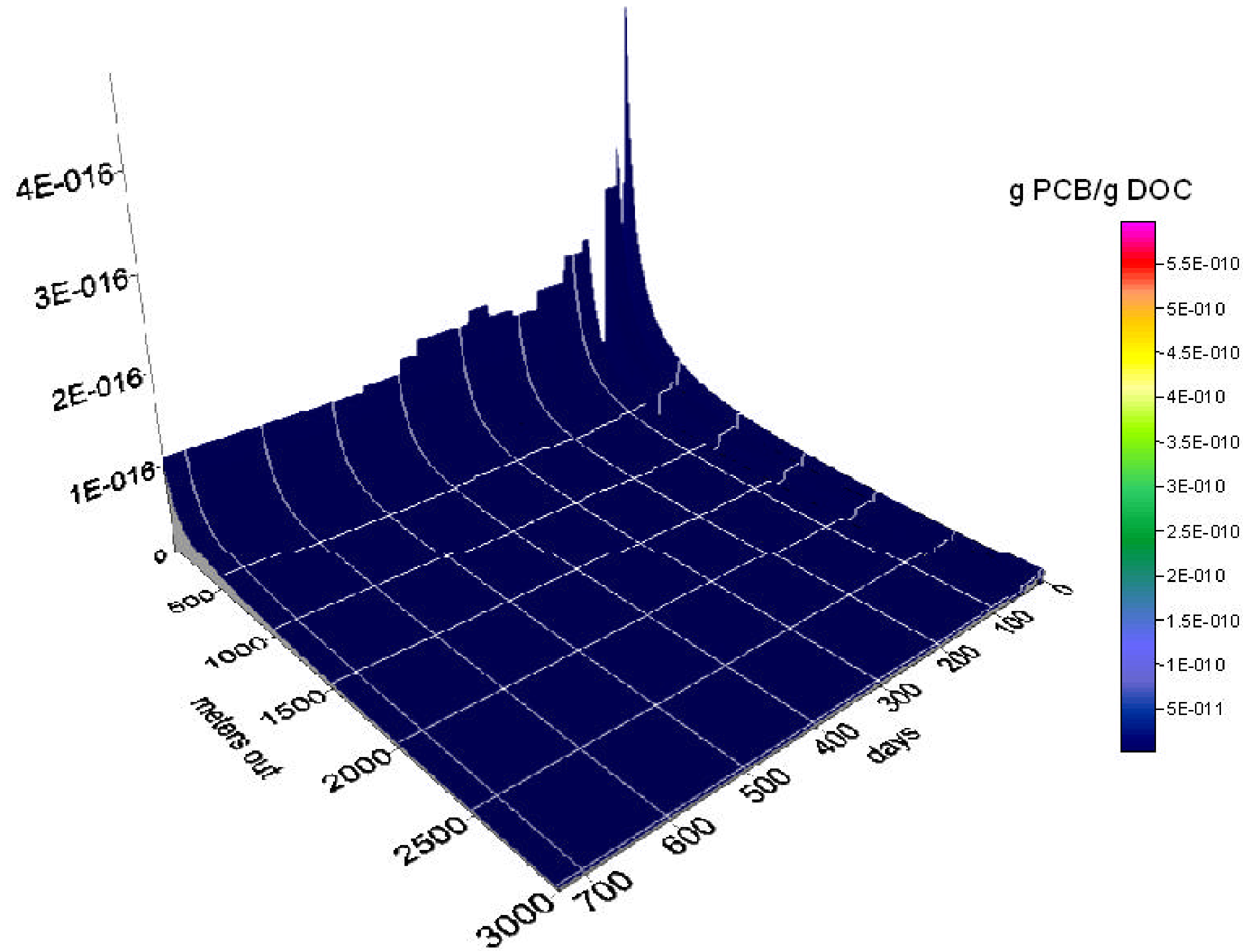


Figure B 13 - Dichlorobiphenyl in DOC below Pycnocline

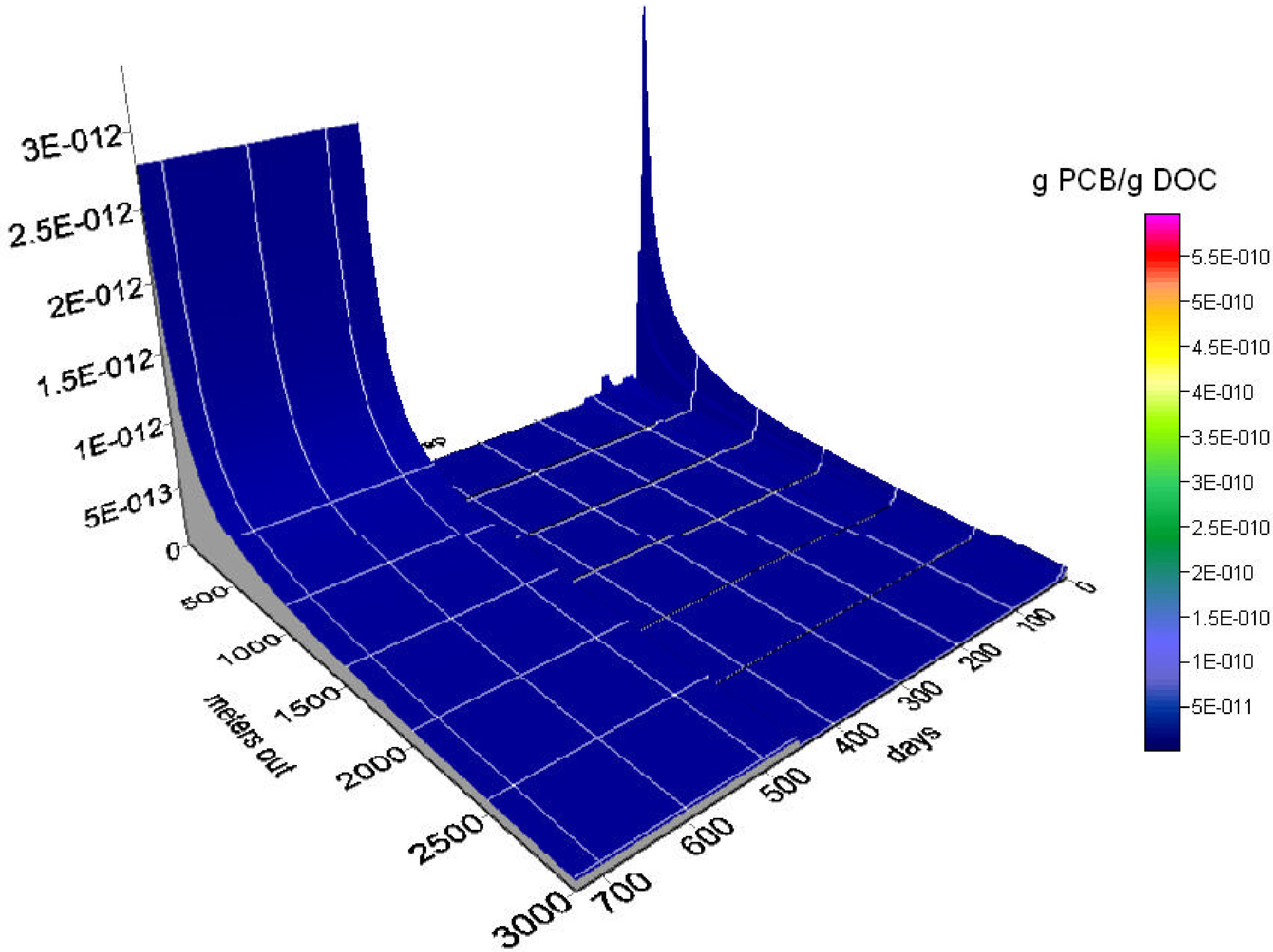


Figure B 14 - Trichlorobiphenyl in DOC below Pycnocline

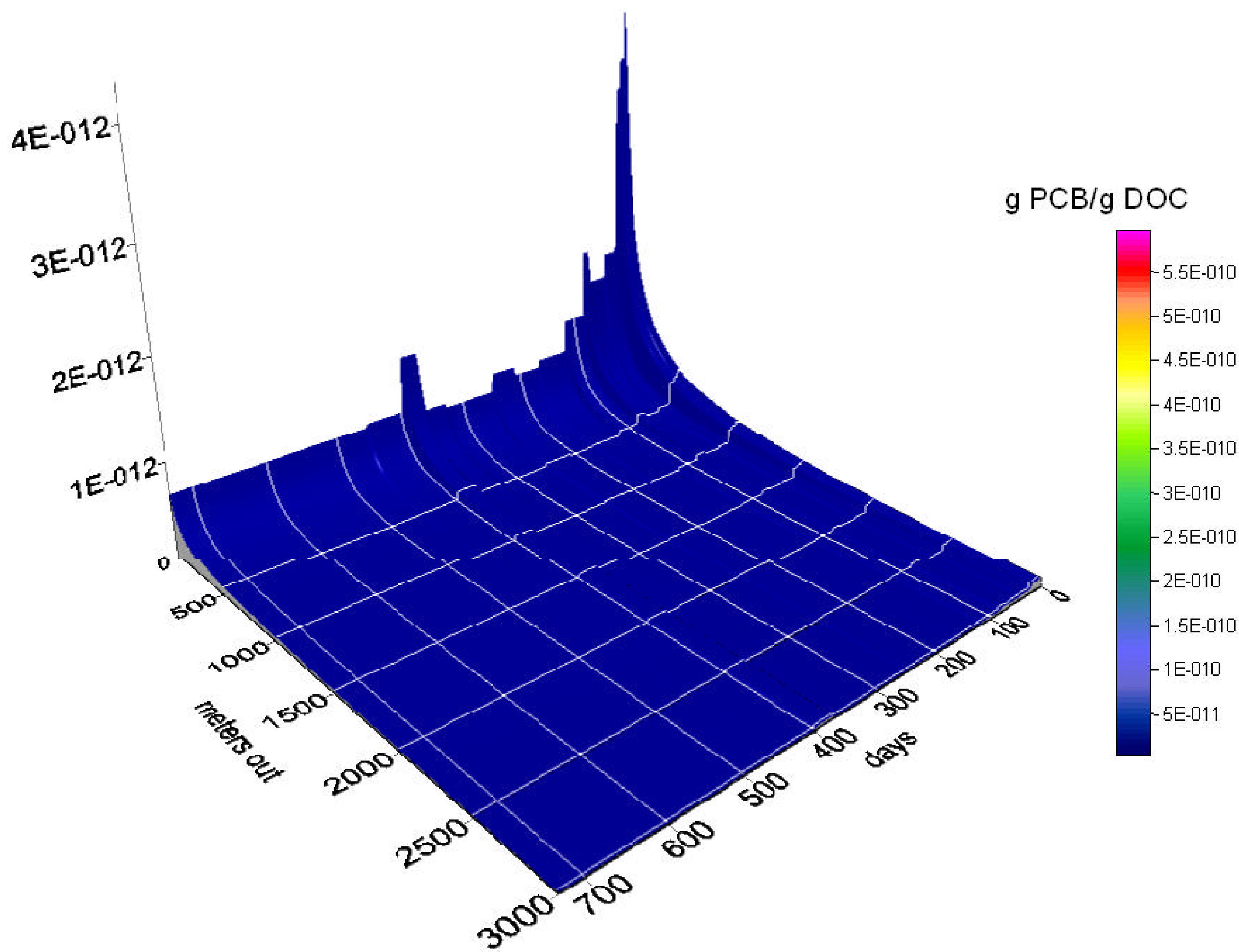


Figure B 15 – Tetrachlorobiphenyl in DOC below Pycnocline

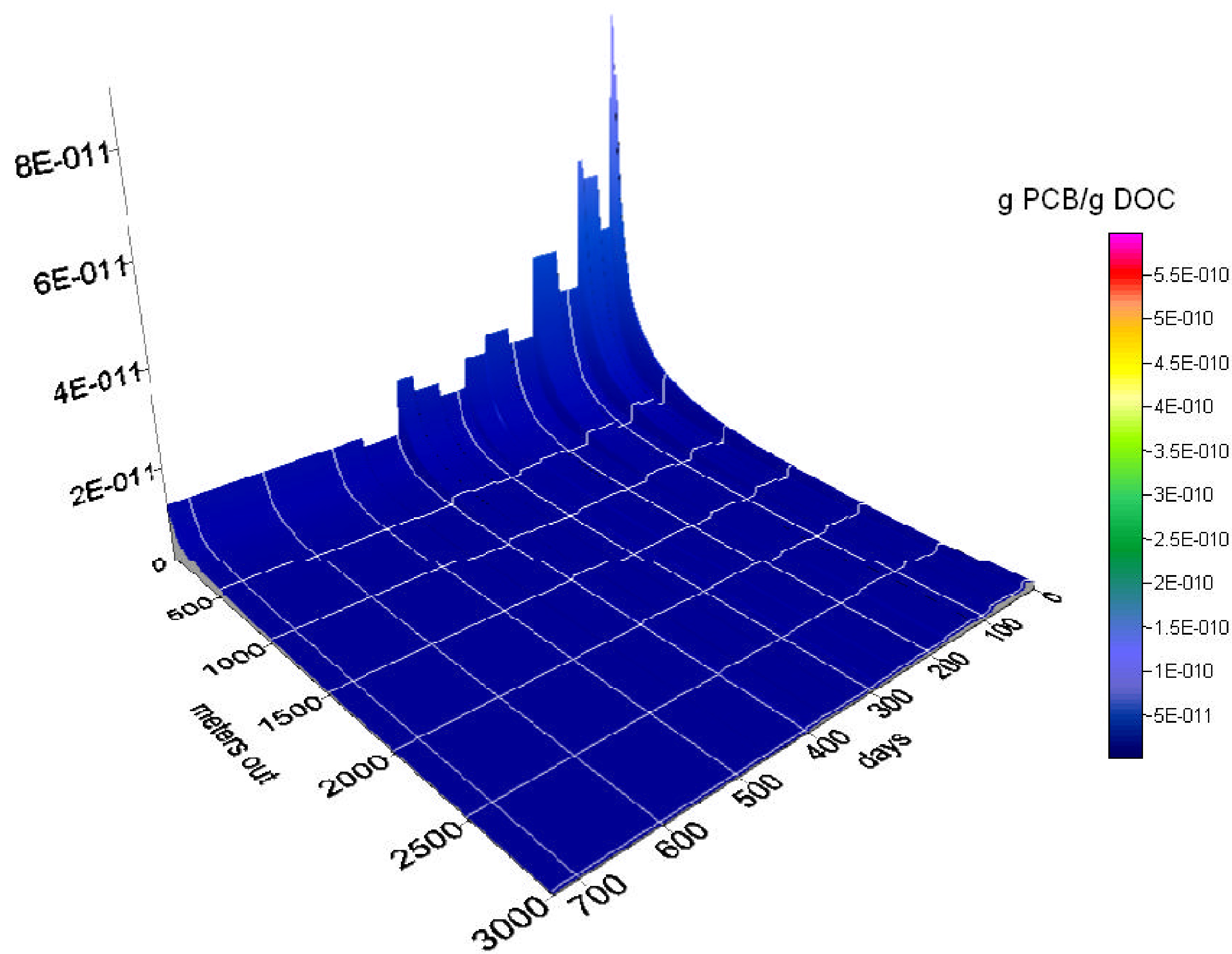


Figure B 16 – Pentachlorobiphenyl in DOC below pycnocline

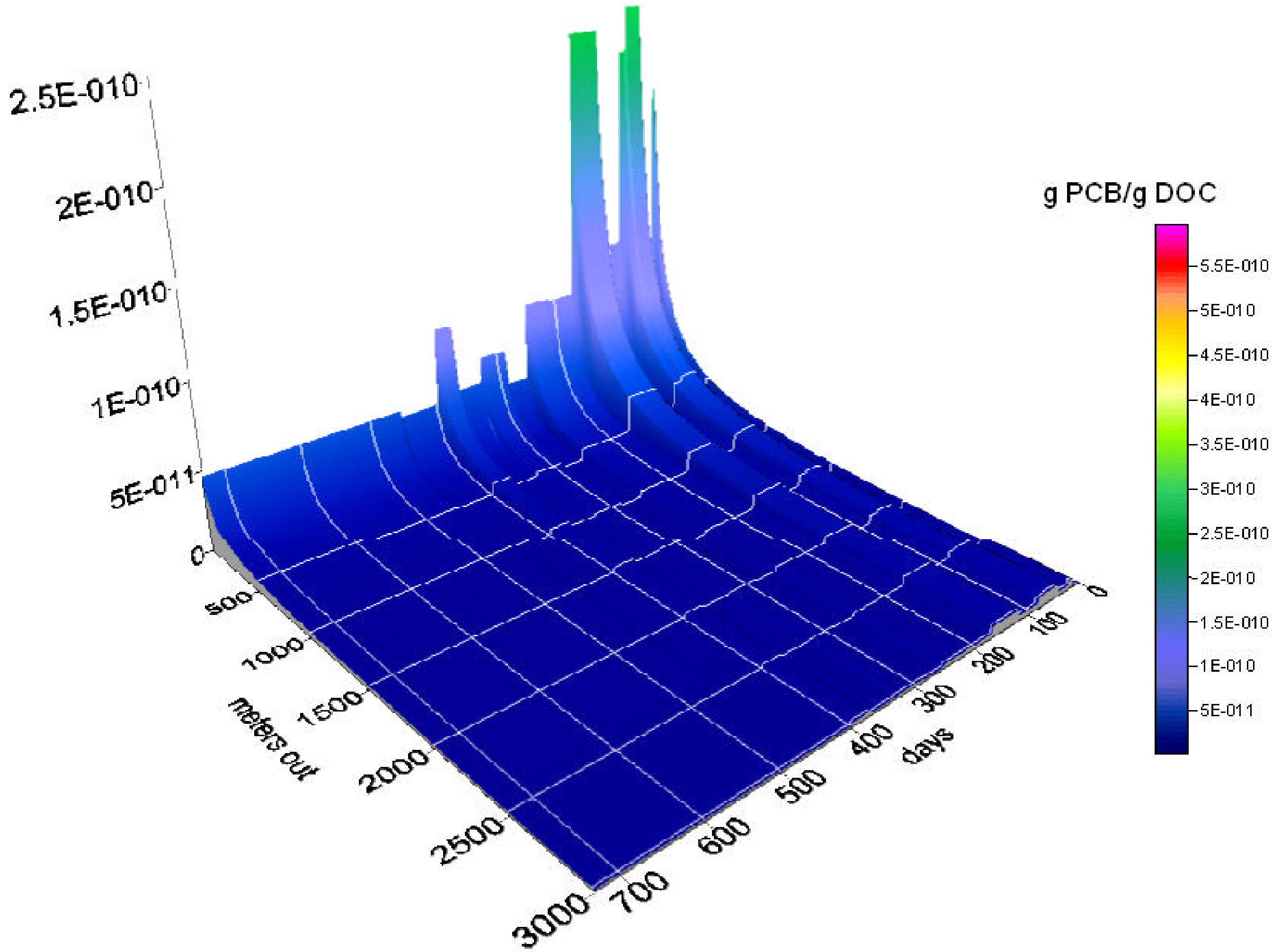


Figure B 17 - Hexachlorobiphenyl in DOC below Pycnocline

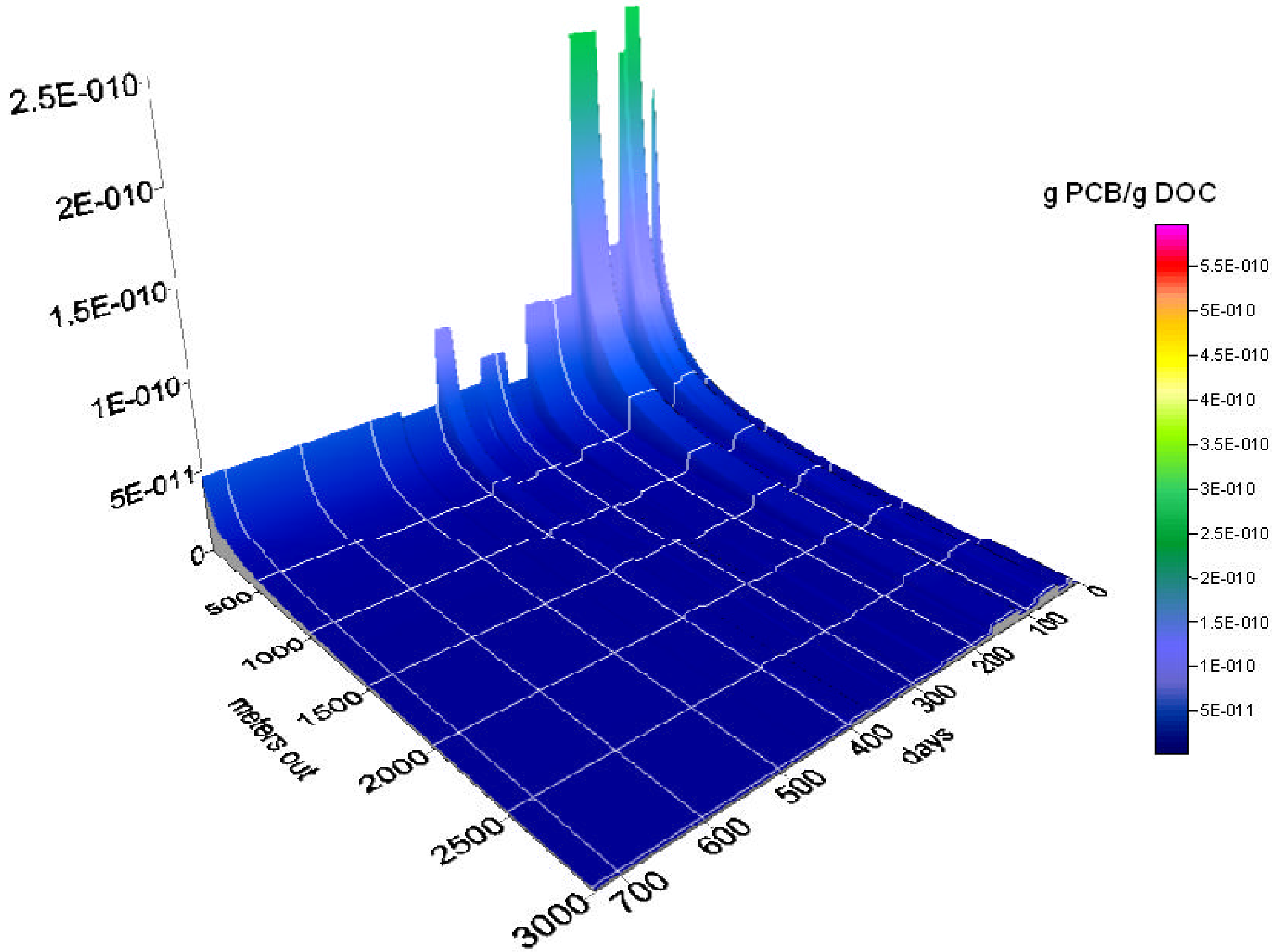


Figure B 18 - Heptachlorobiphenyl in DOC below Pycnocline

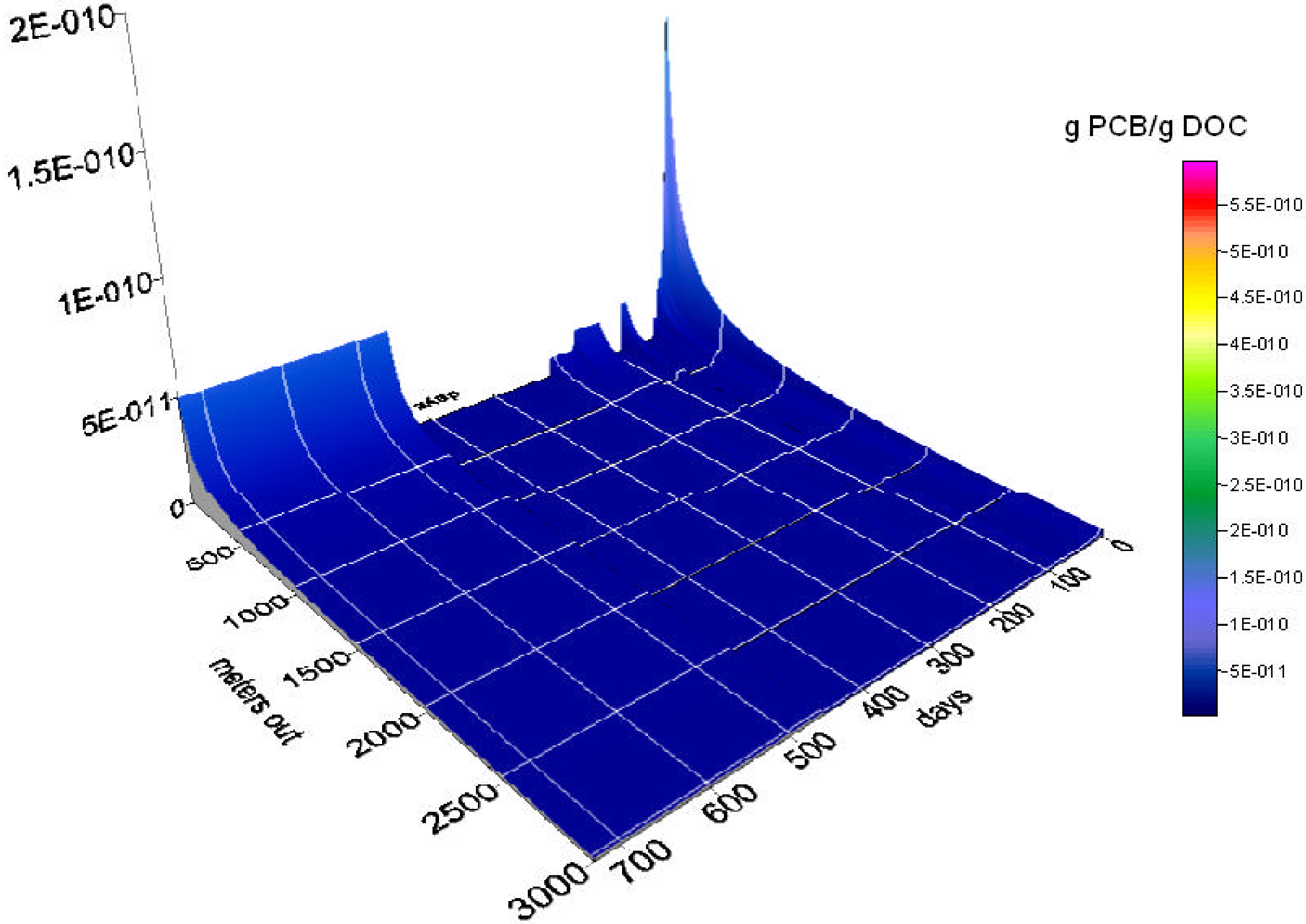


Figure B 19 – Nonachlorobiphenyl in DOC below Pycnocline

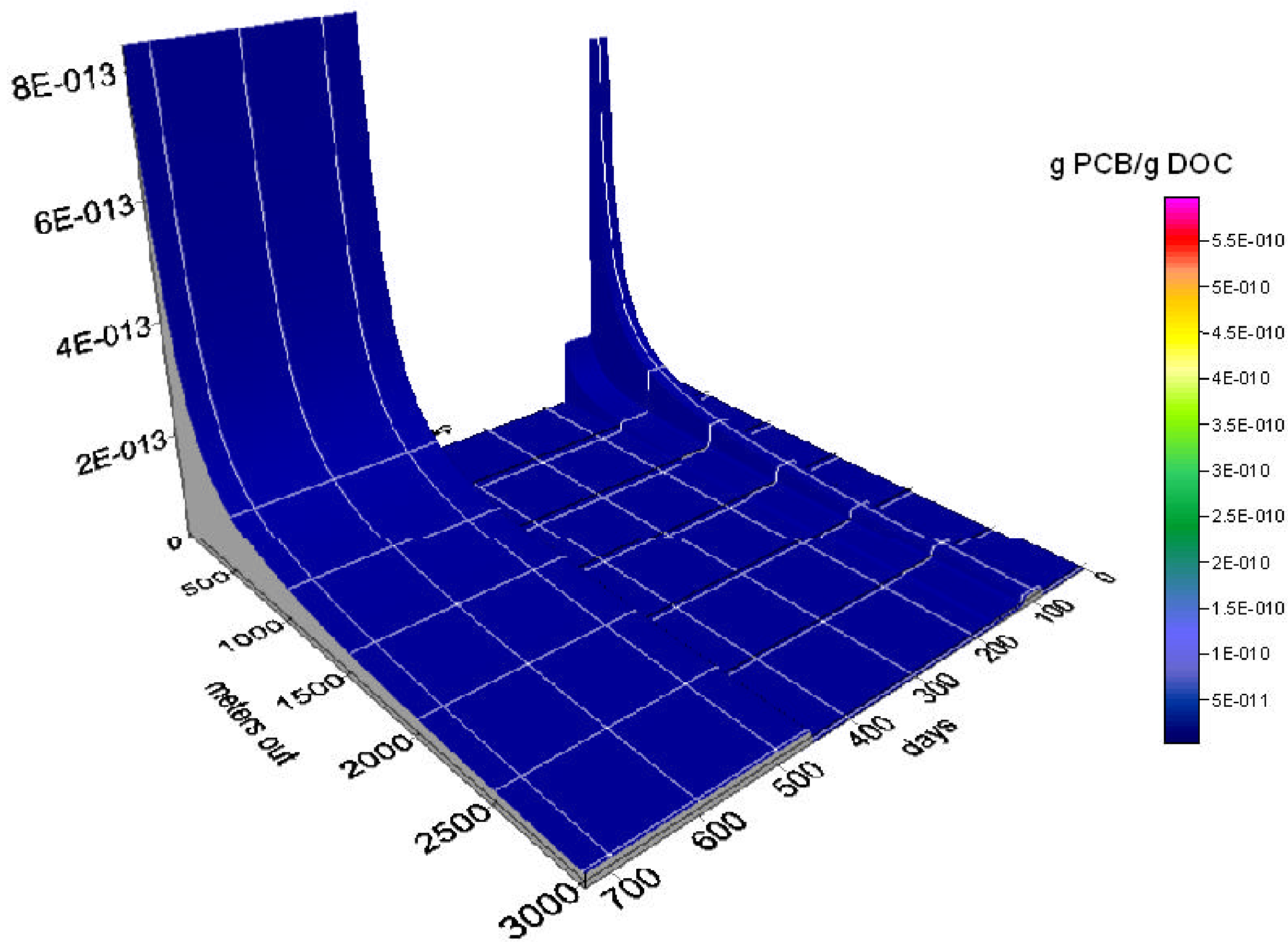


Figure B 20 - Decachlorobiphenyl in DOC below Pycnocline

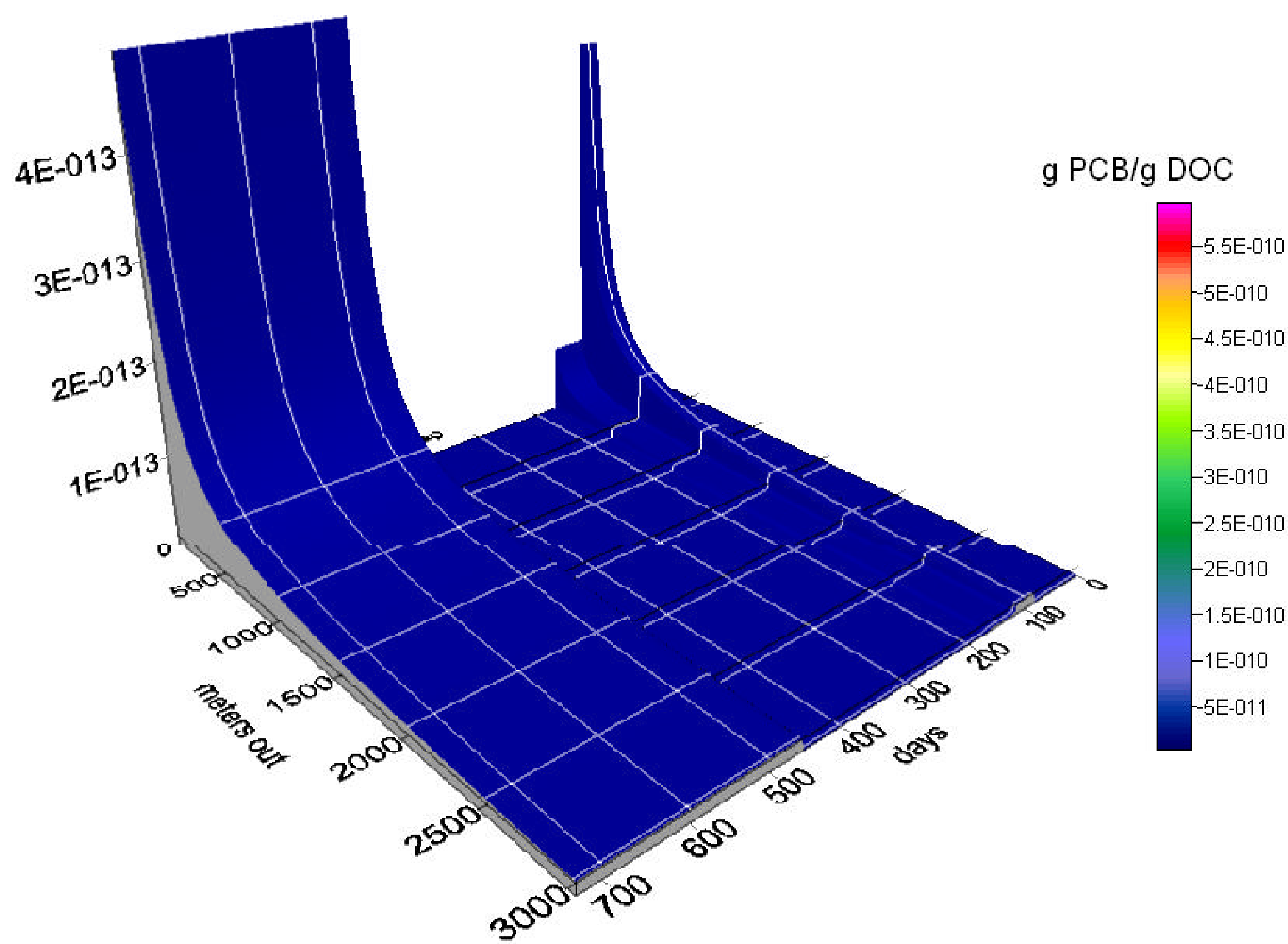


Figure B 21 - Total PCB in TSS below Pycnocline

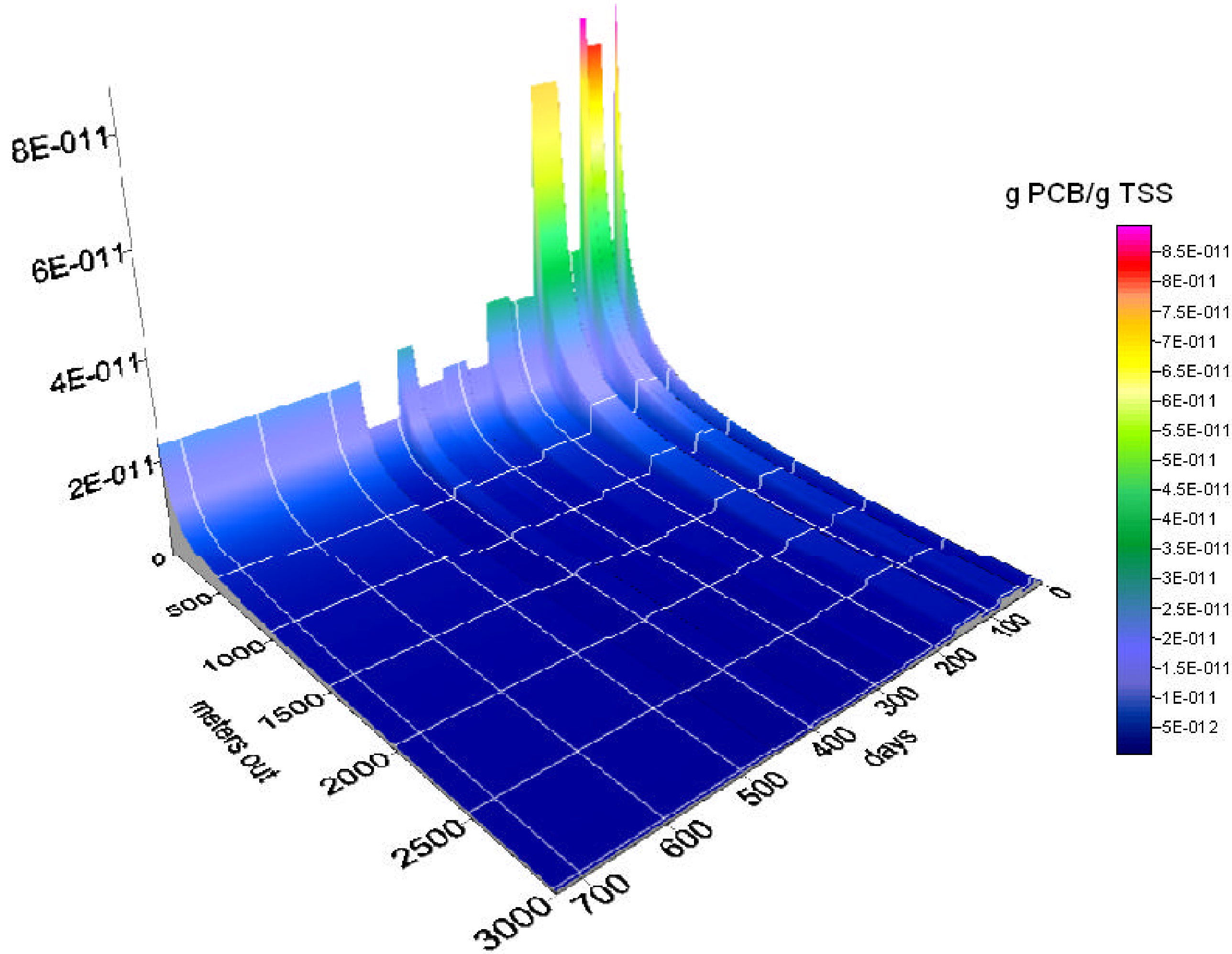


Figure B 22 – Monochlorobiphenyl in TSS below Pycnocline

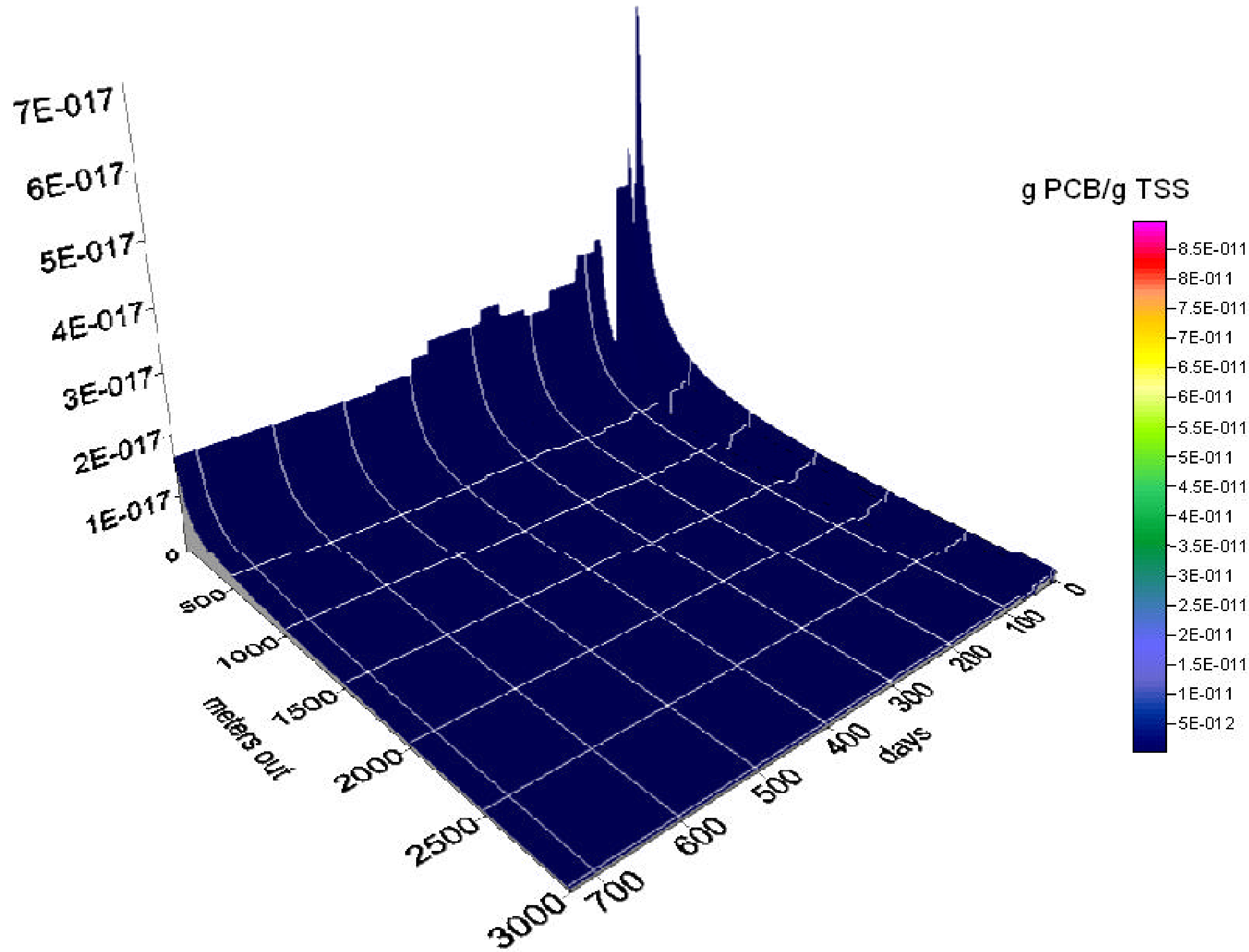


Figure B 23 - Dichlorobiphenyl in TSS below Pycnocline

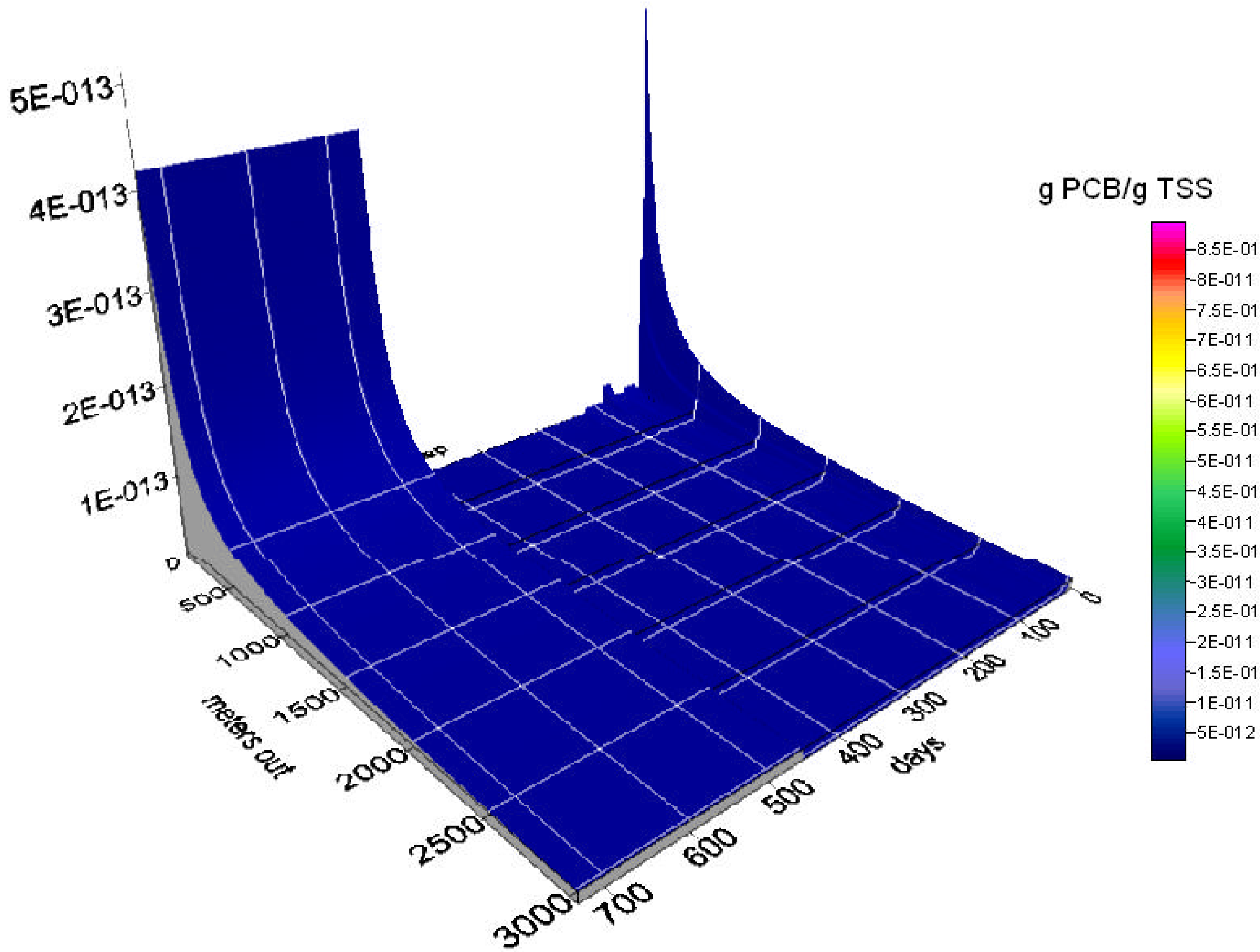


Figure B 24 - Trichlorobiphenyl in TSS below Pycnocline

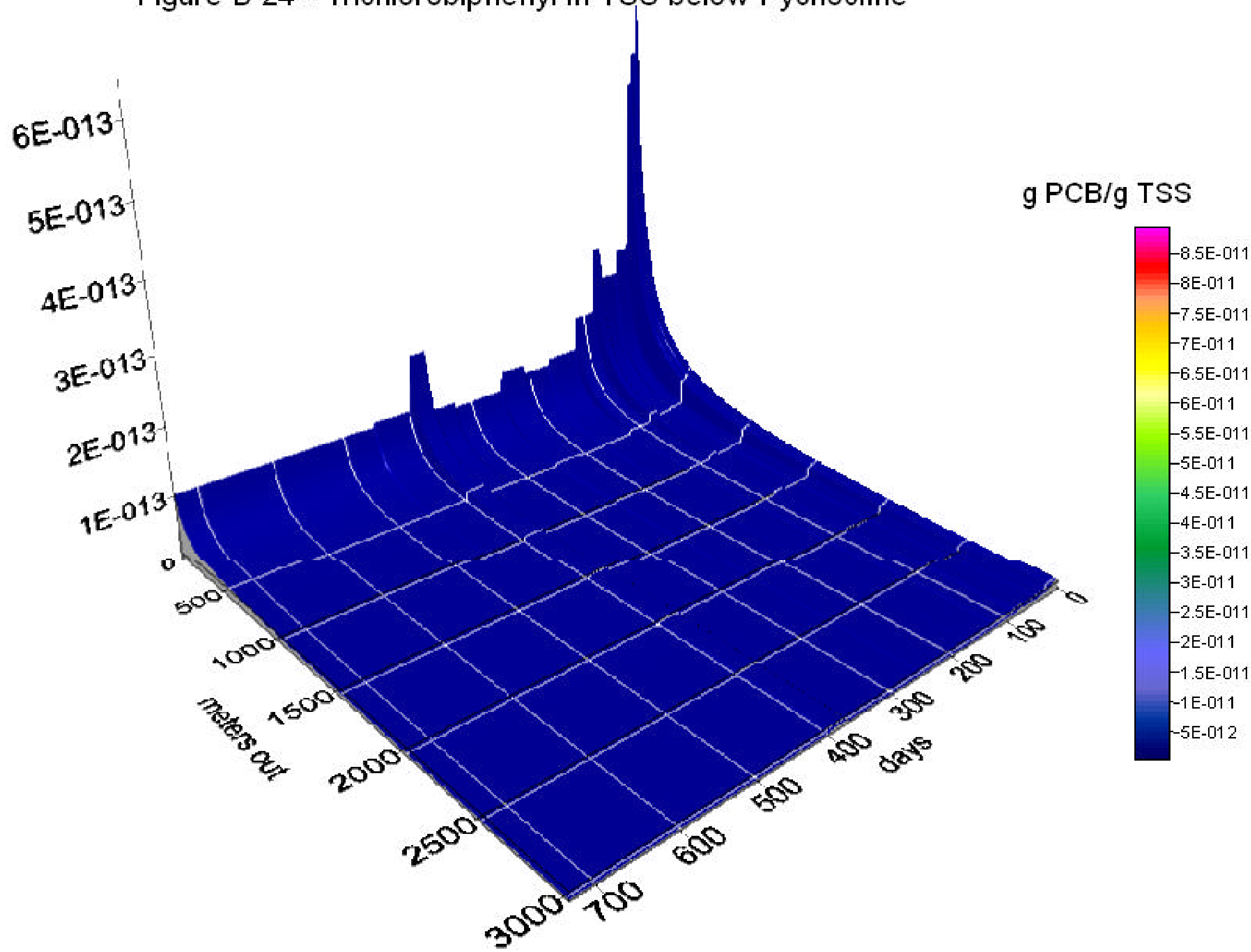


Figure B 25 - Tetrachlorobiphenyl in TSS below Pycnocline

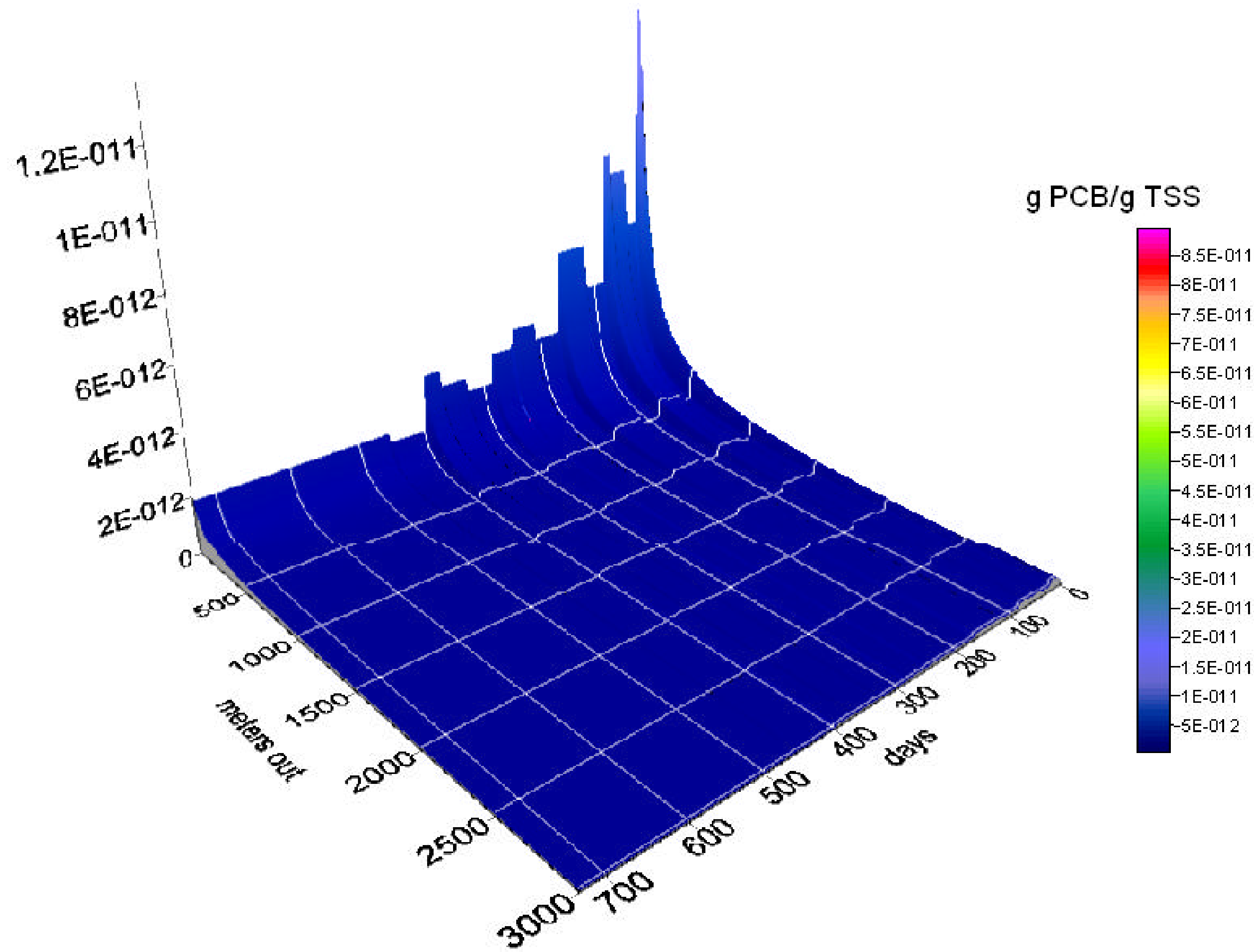


Figure B 26 - Pentachlorobiphenyl in TSS below Pycnocline

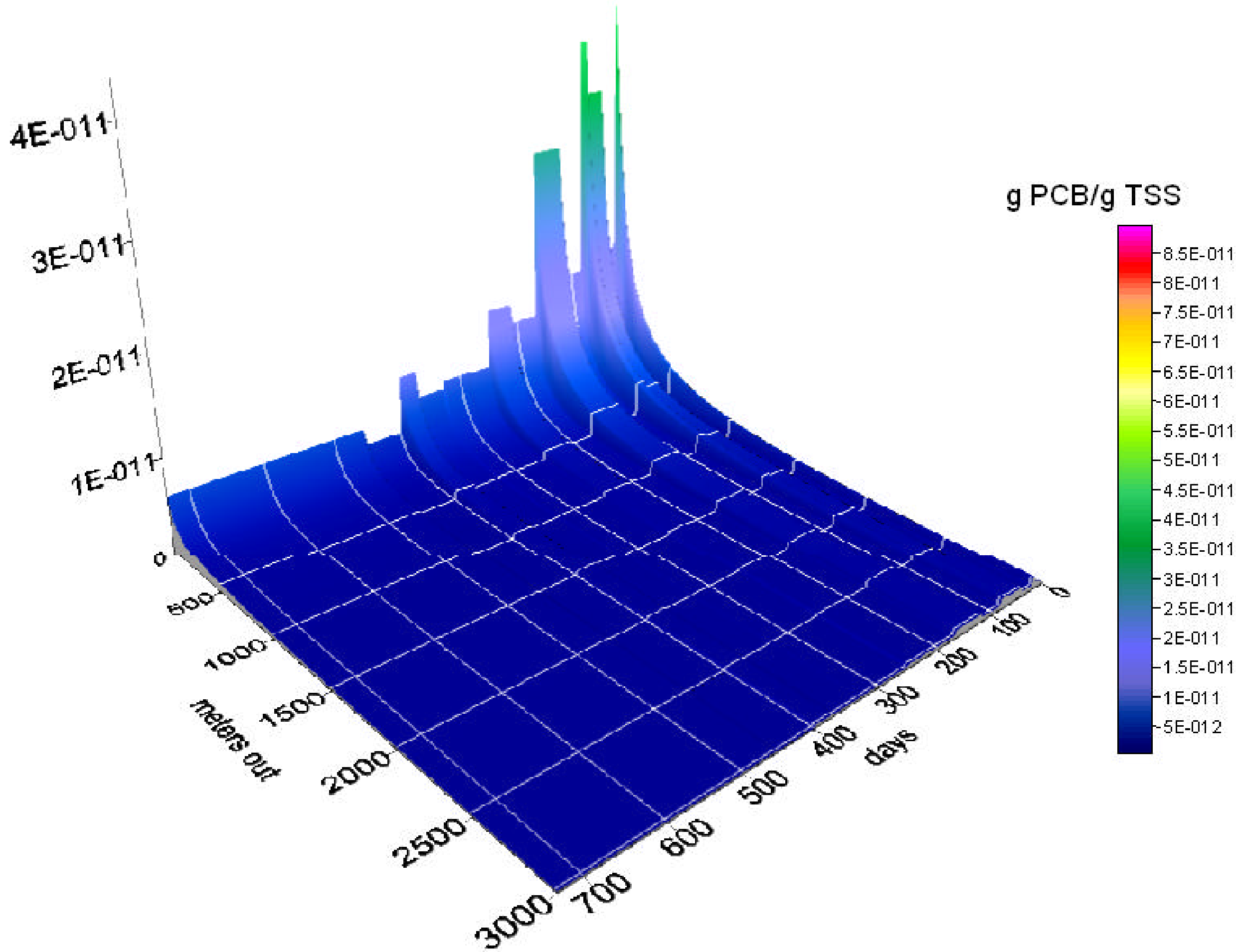


Figure B 27 - Hexachlorobiphenyl in TSS below Pycnocline

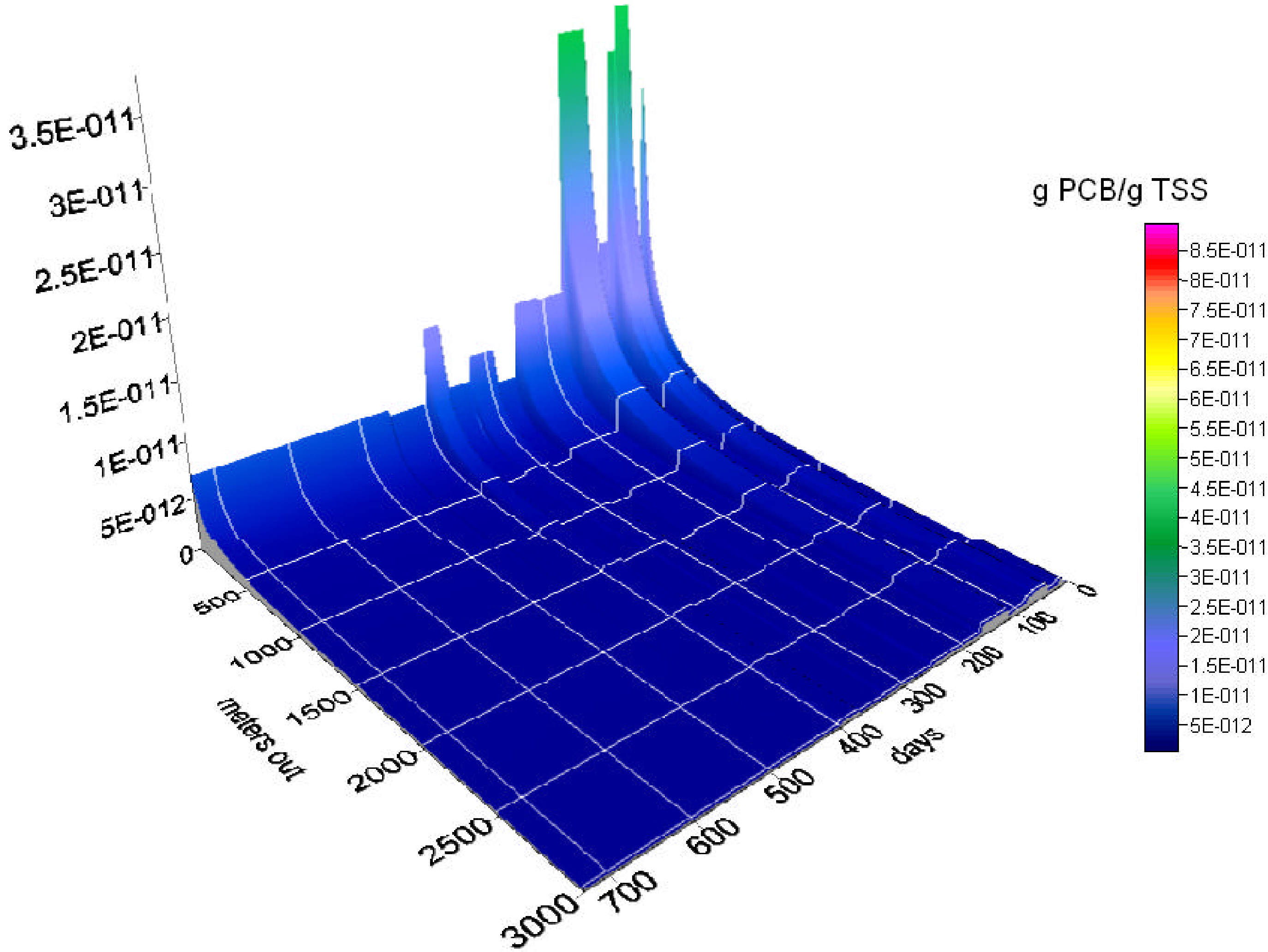


Figure B 28 - Heptachlorobiphenyl in TSS below Pycnocline

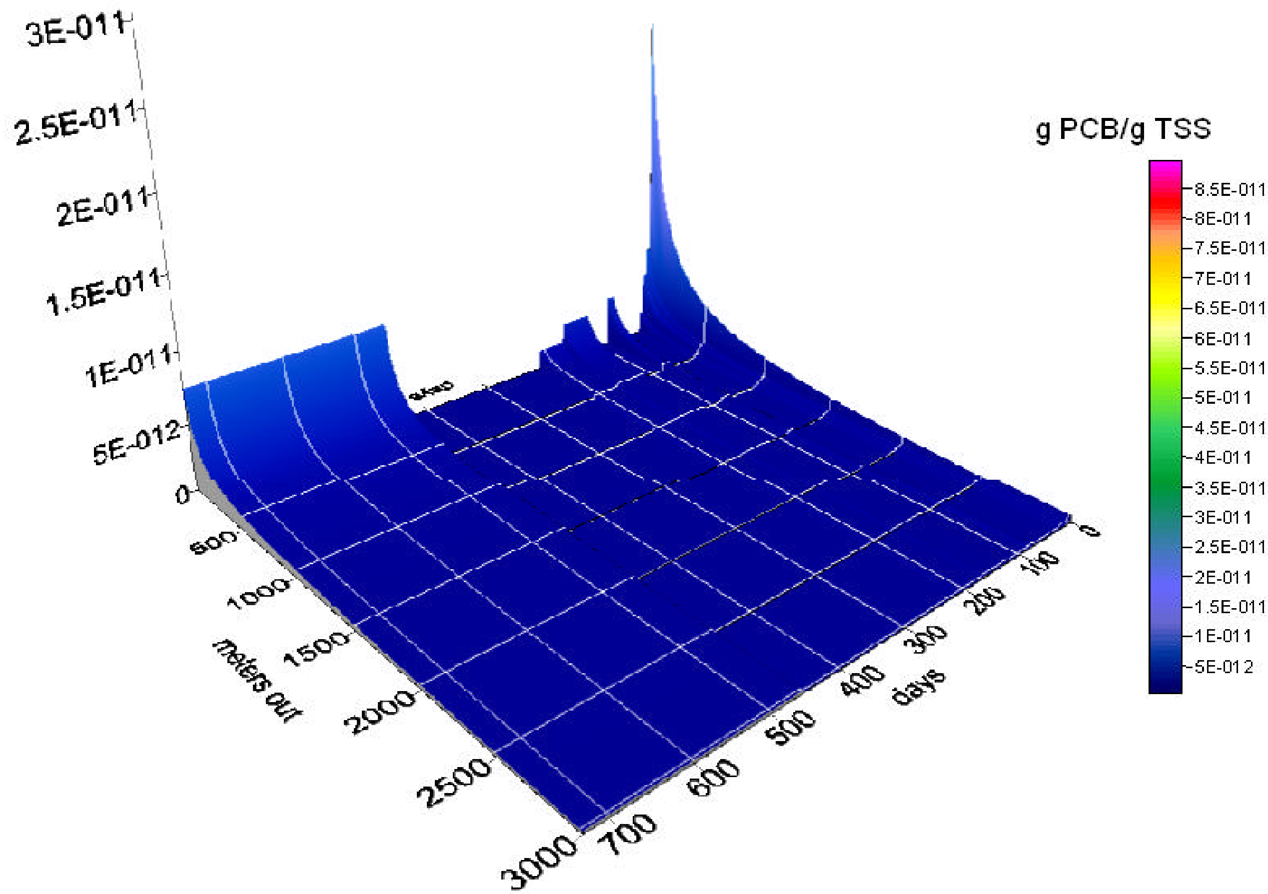


Figure B 29 - Nonachlorobiphenyl in TSS below Pycnocline

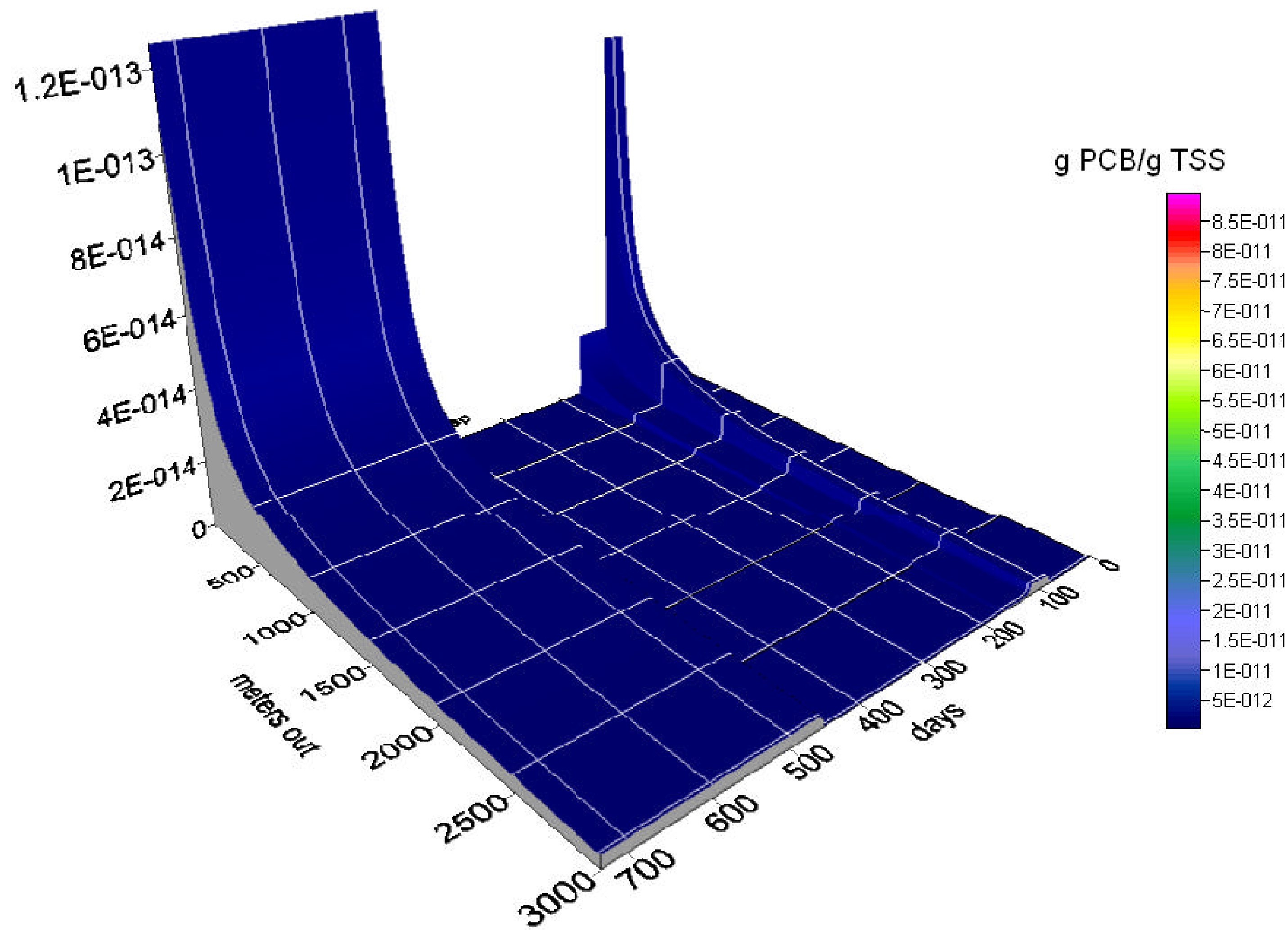


Figure B 30 - Decachlorobiphenyl in TSS below Pycnocline

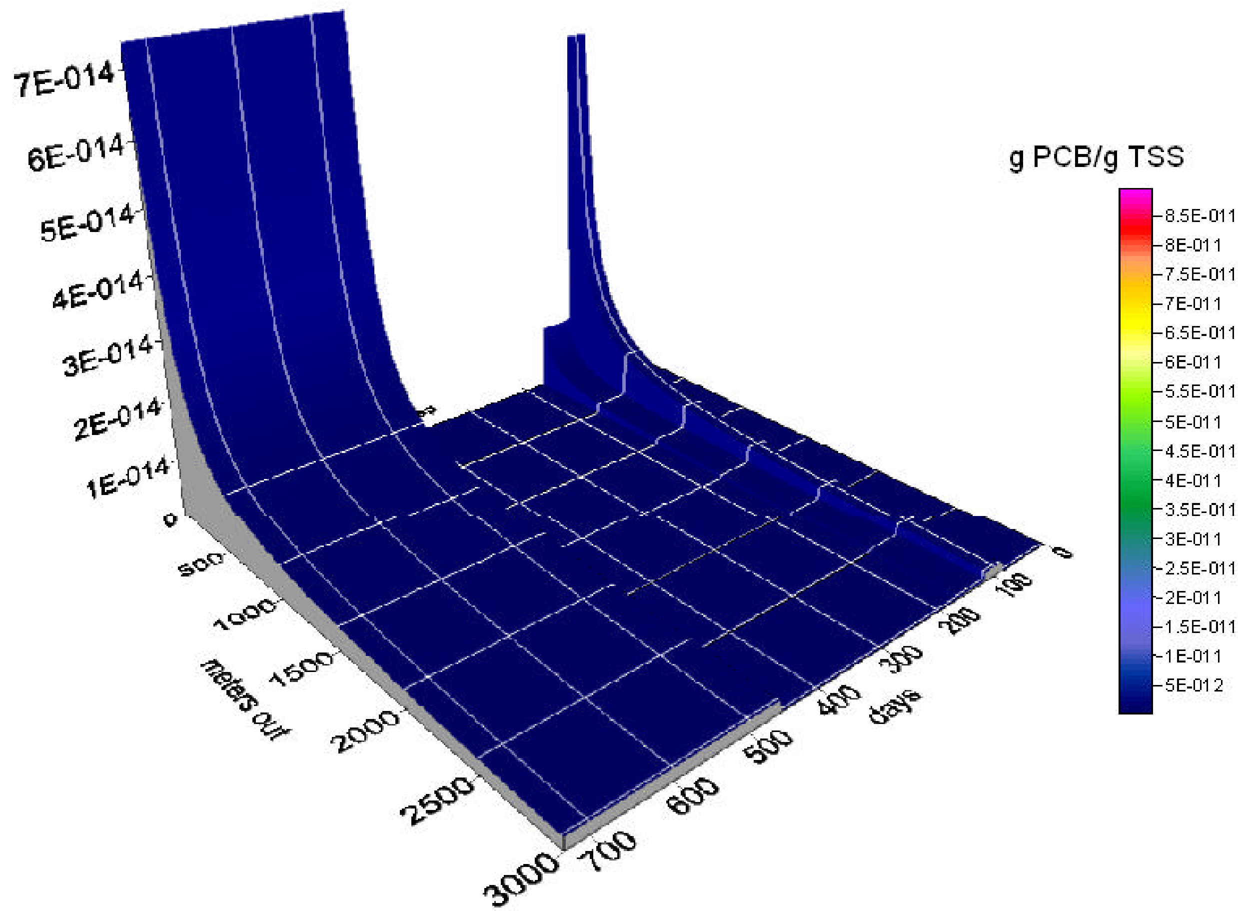


Figure B 31 - Total PCB in Sediment

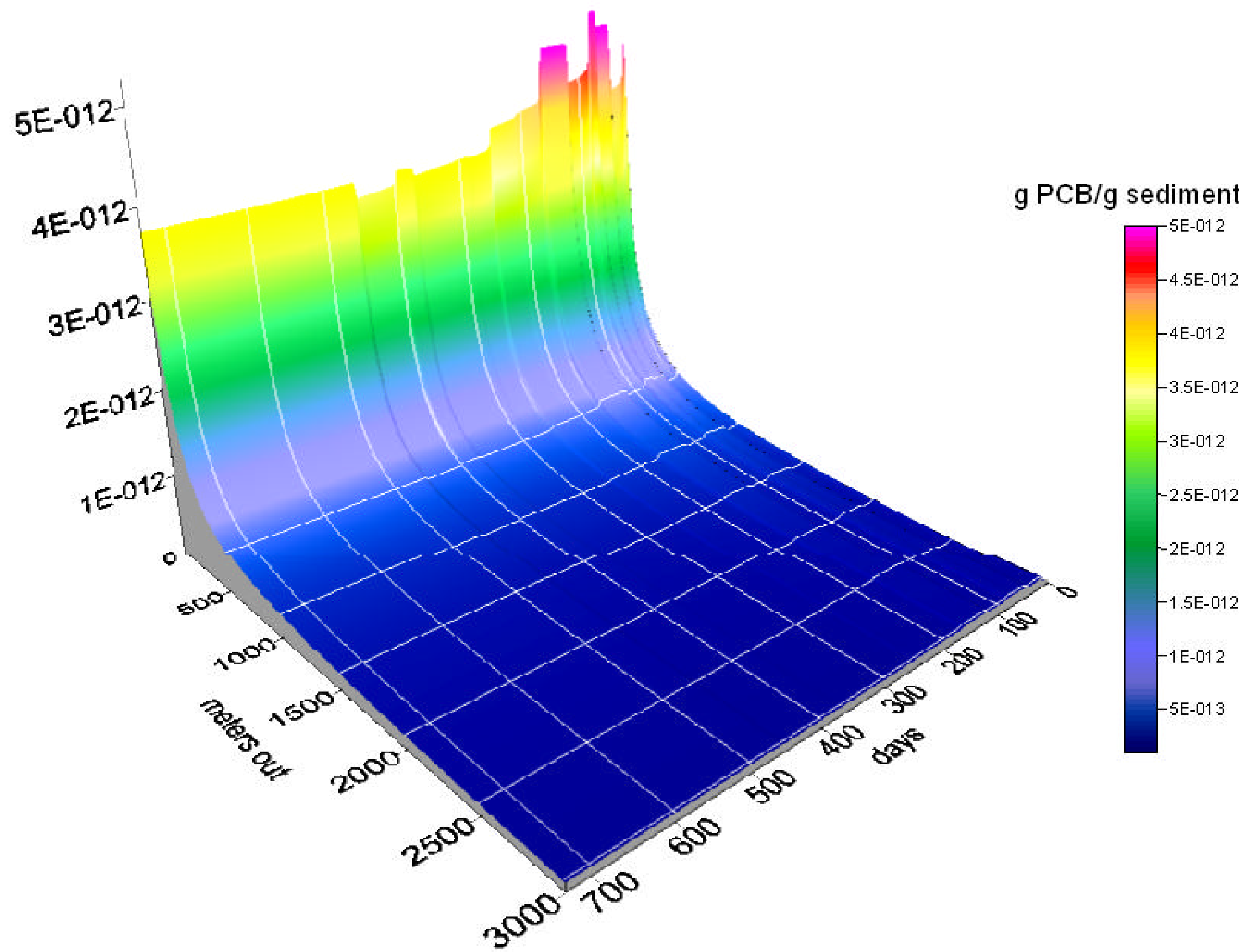


Figure B 32 – Monochlorobiphenyl in Sediment

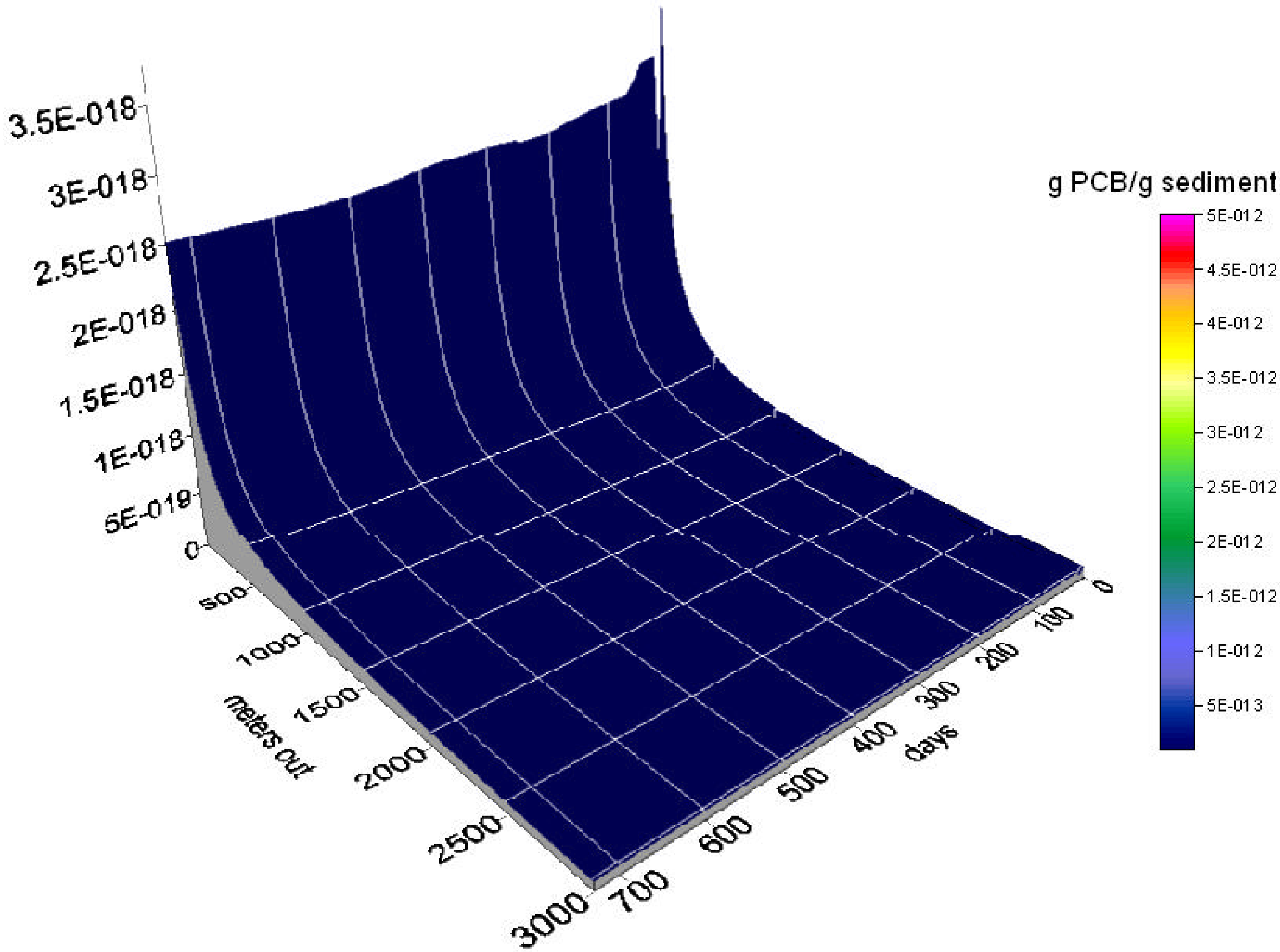


Figure B 33 – Dichlorobiphenyl in Sediment

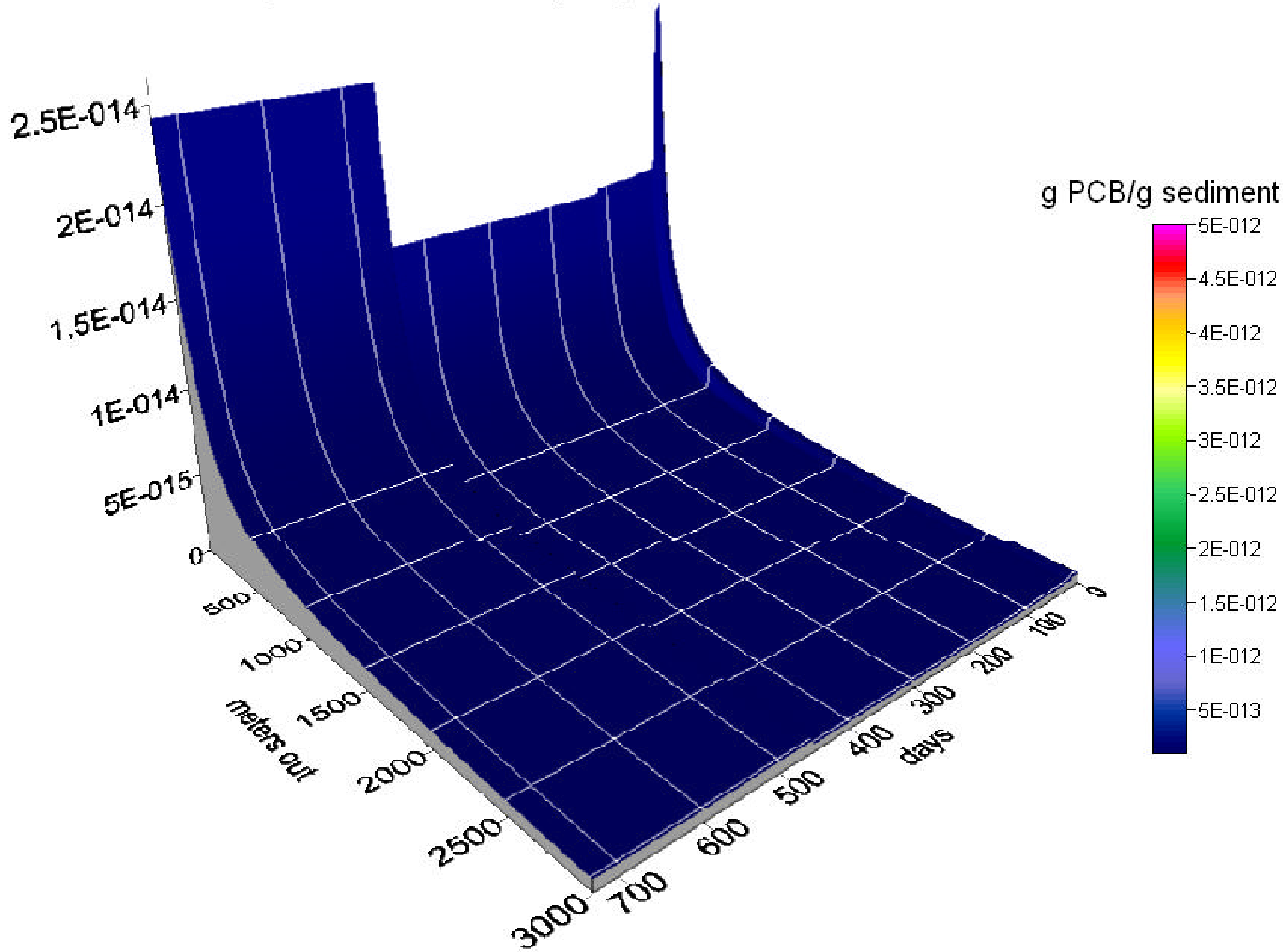


Figure B 34 – Trichlorobiphenyl in Sediment

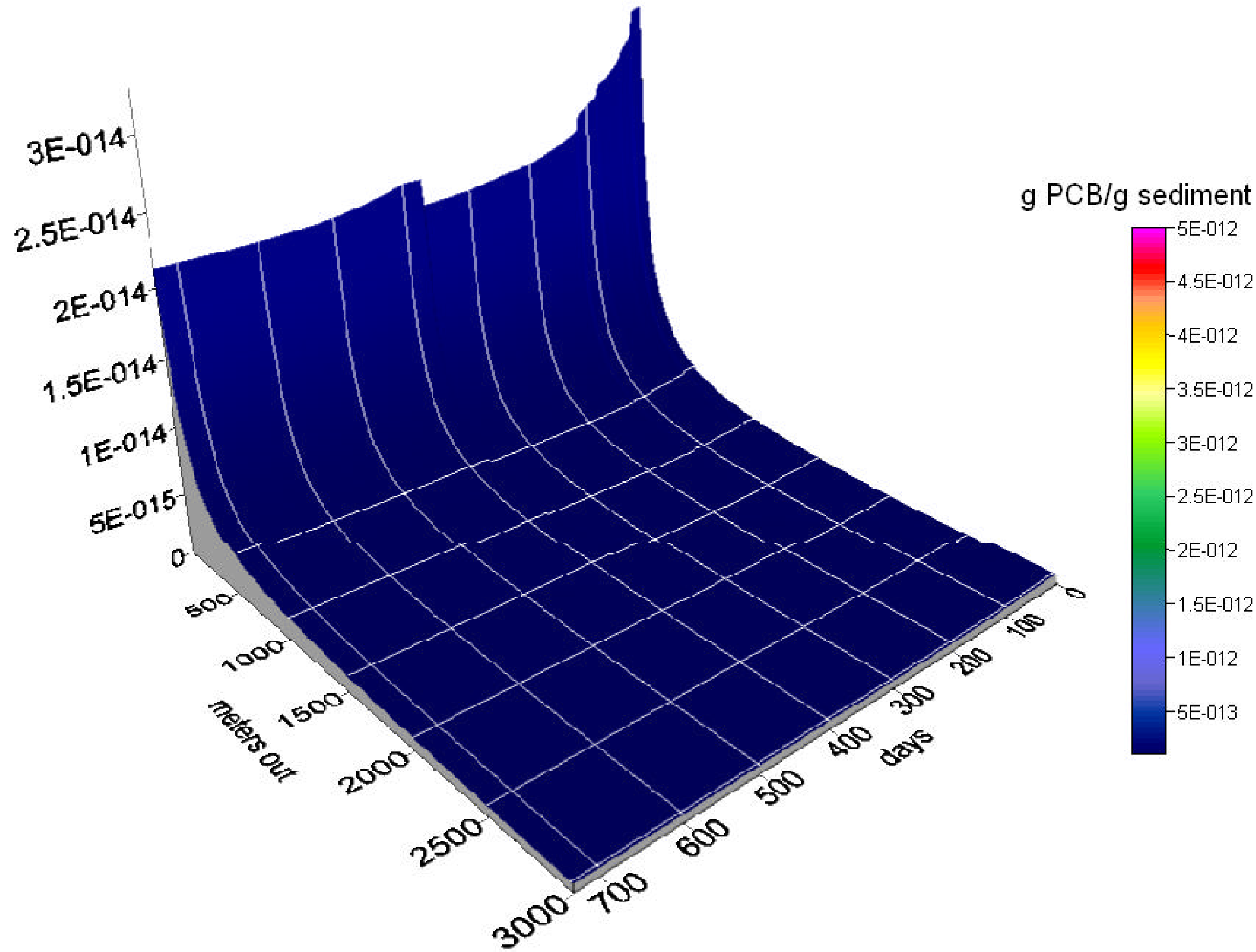


Figure B 35 - Tetrachlorobiphenyl in Sediment

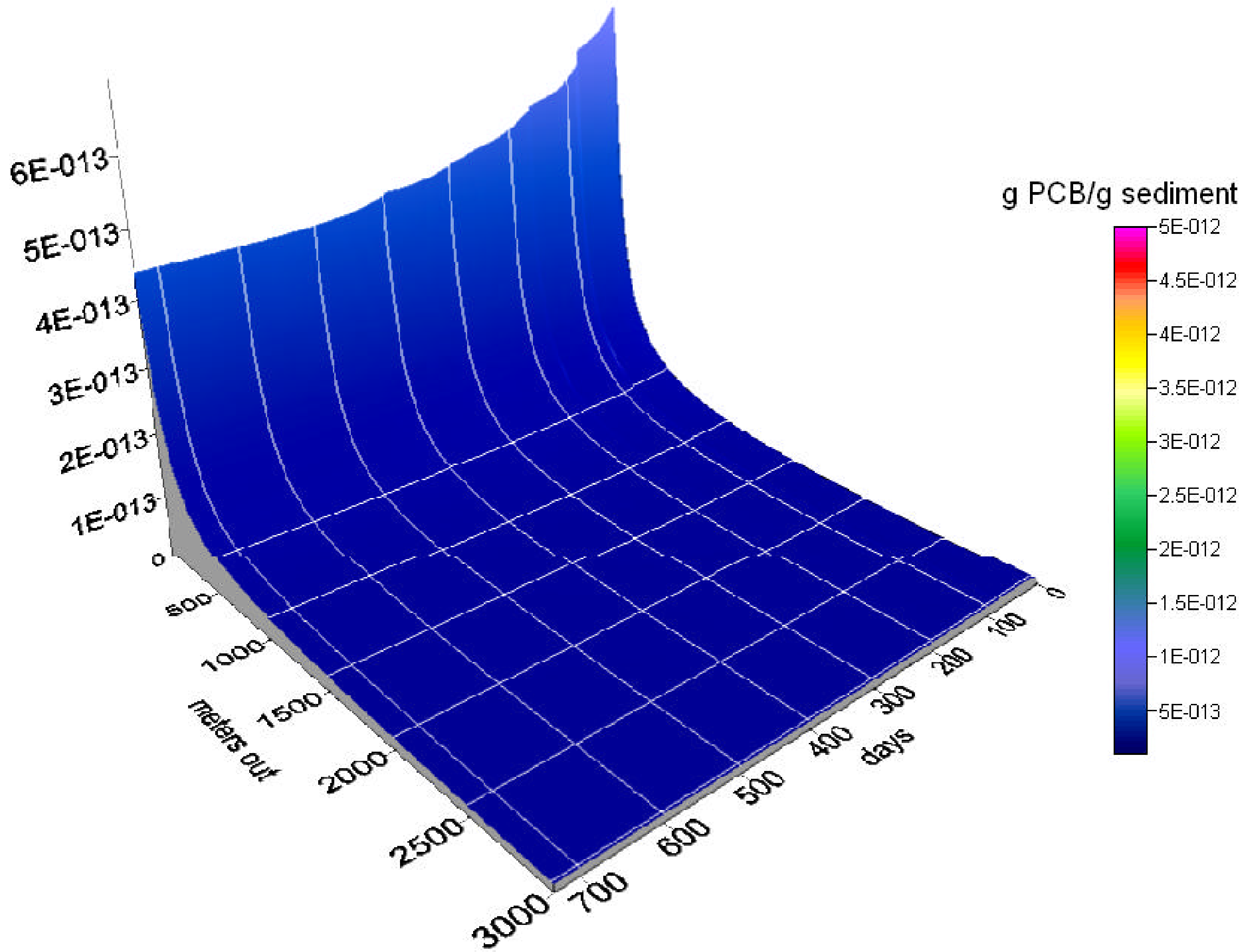


Figure B 36 – Pentachlorobiphenyl in Sediment

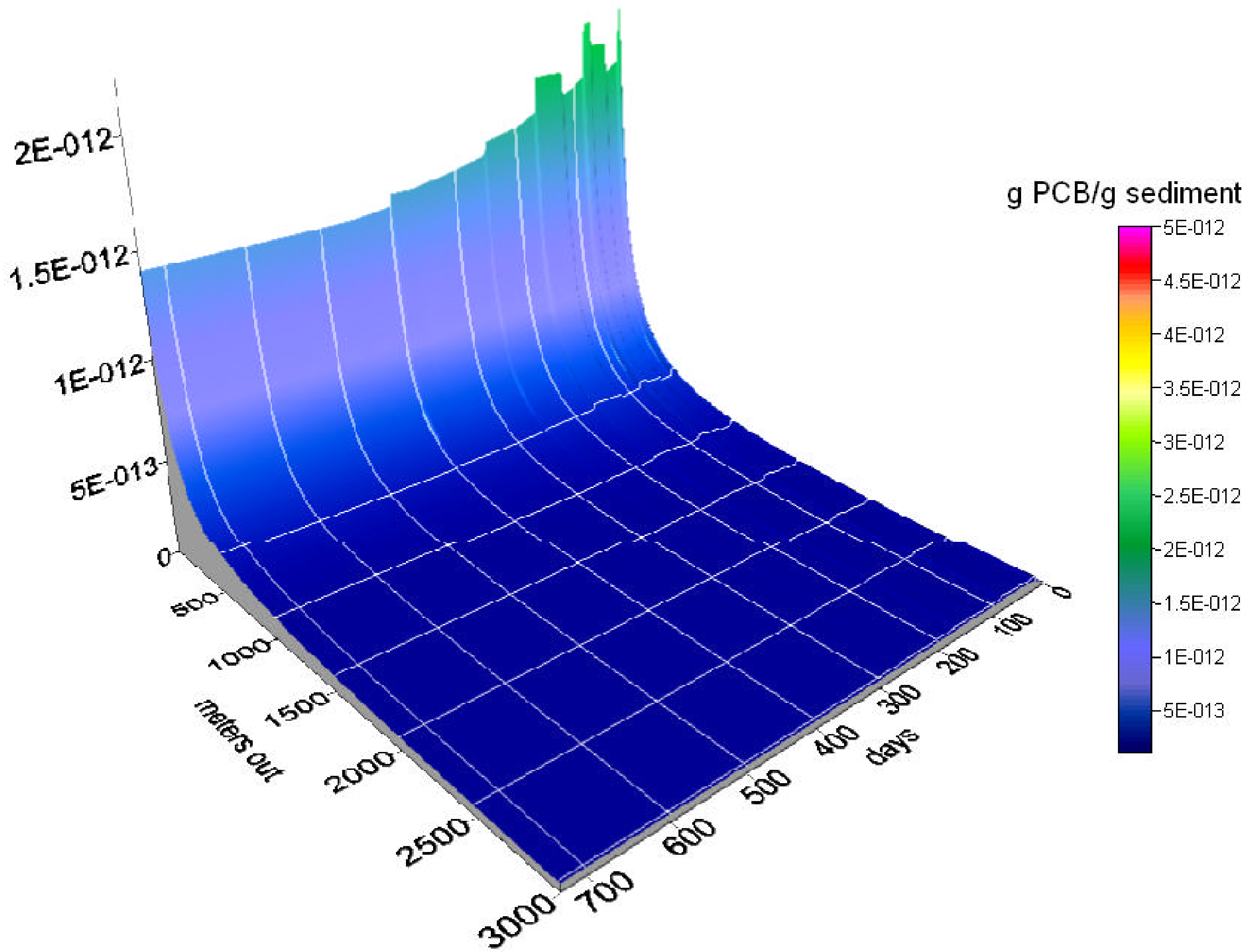


Figure B 37 – Hexachlorobiphenyl in Sediment

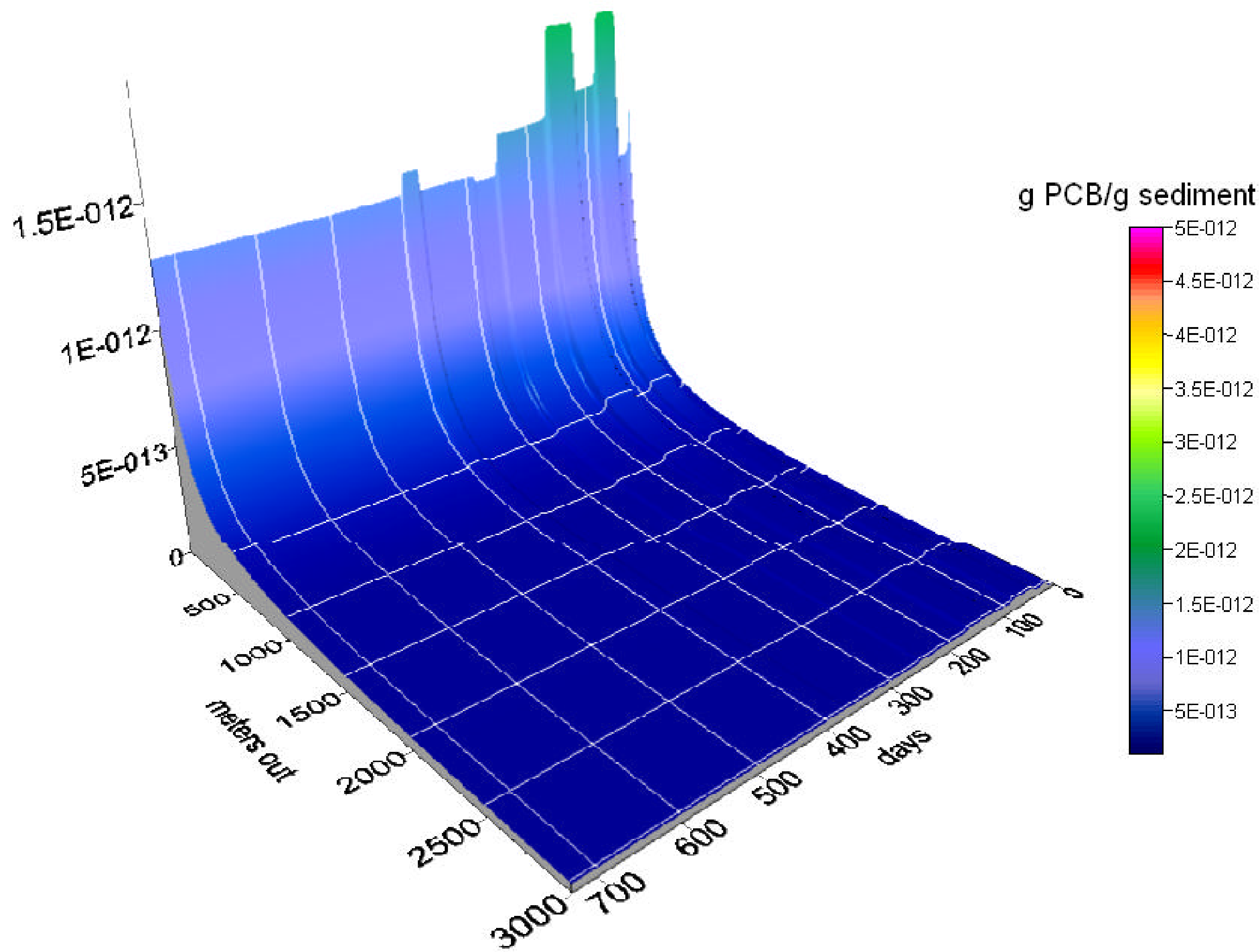


Figure B 38 – Heptachlorobiphenyl in Sediment

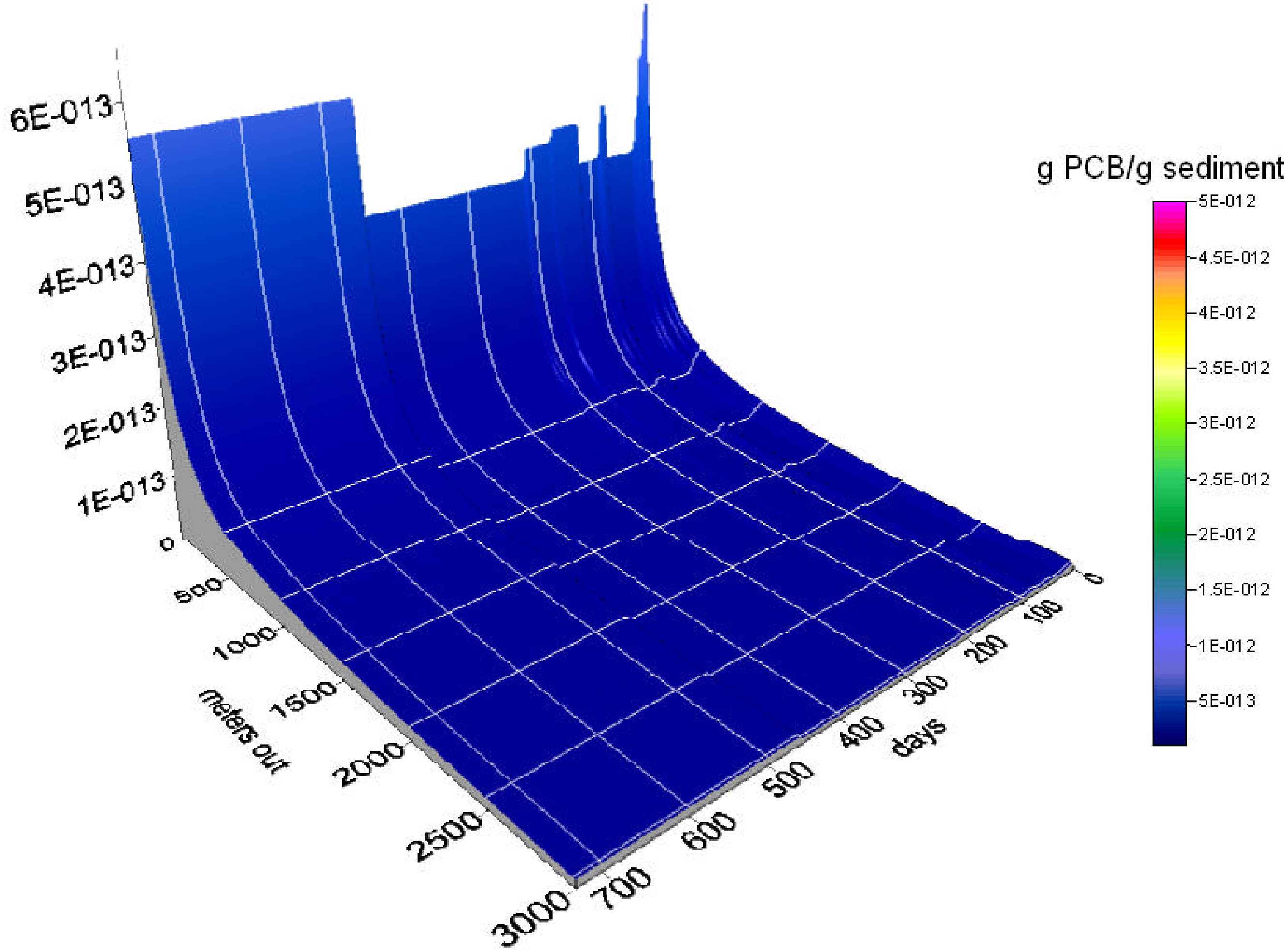


Figure B 39 – Nonachlorobiphenyl in Sediment

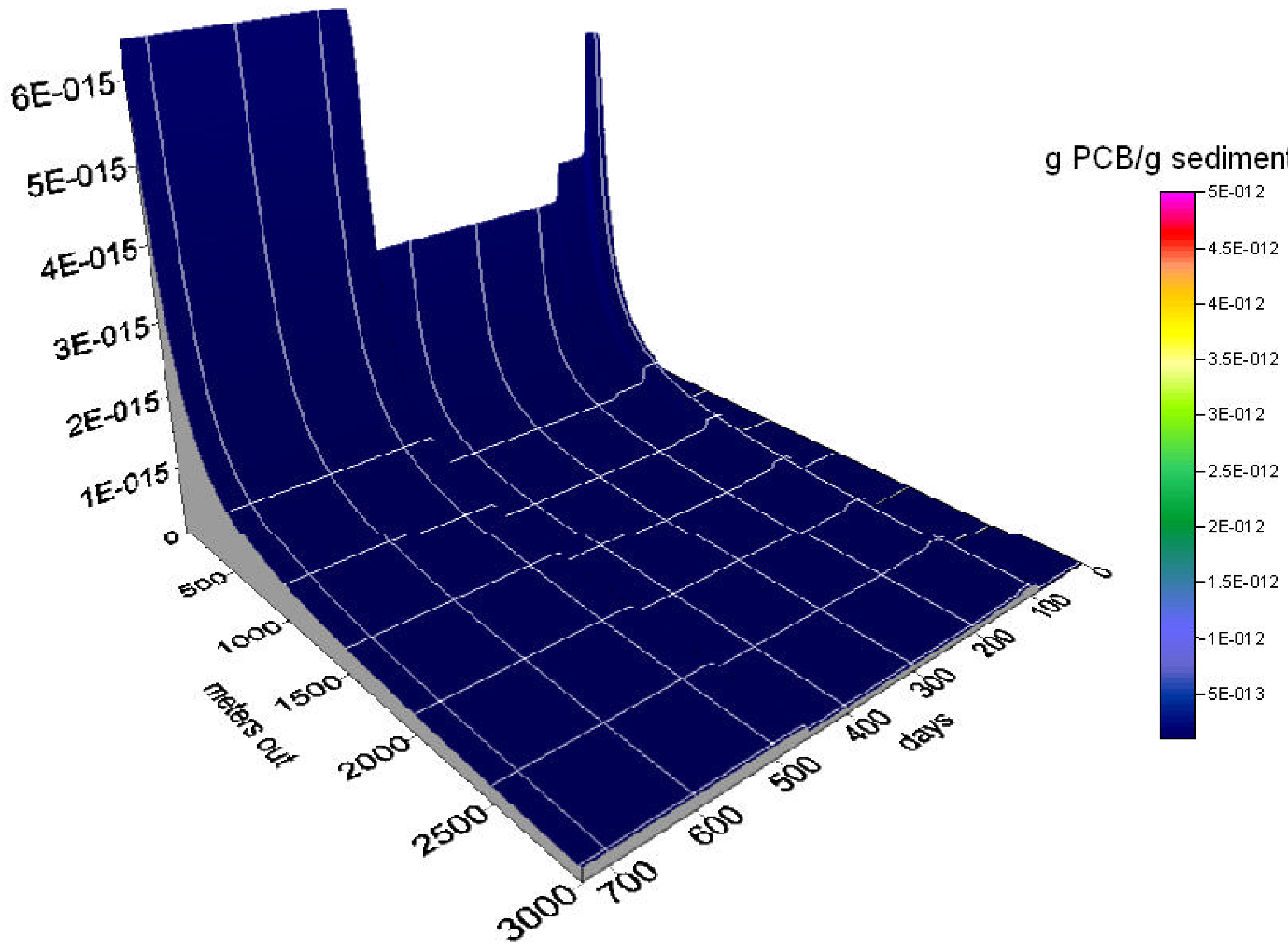


Figure B 40 – Decachlorobiphenyl in Sediment n

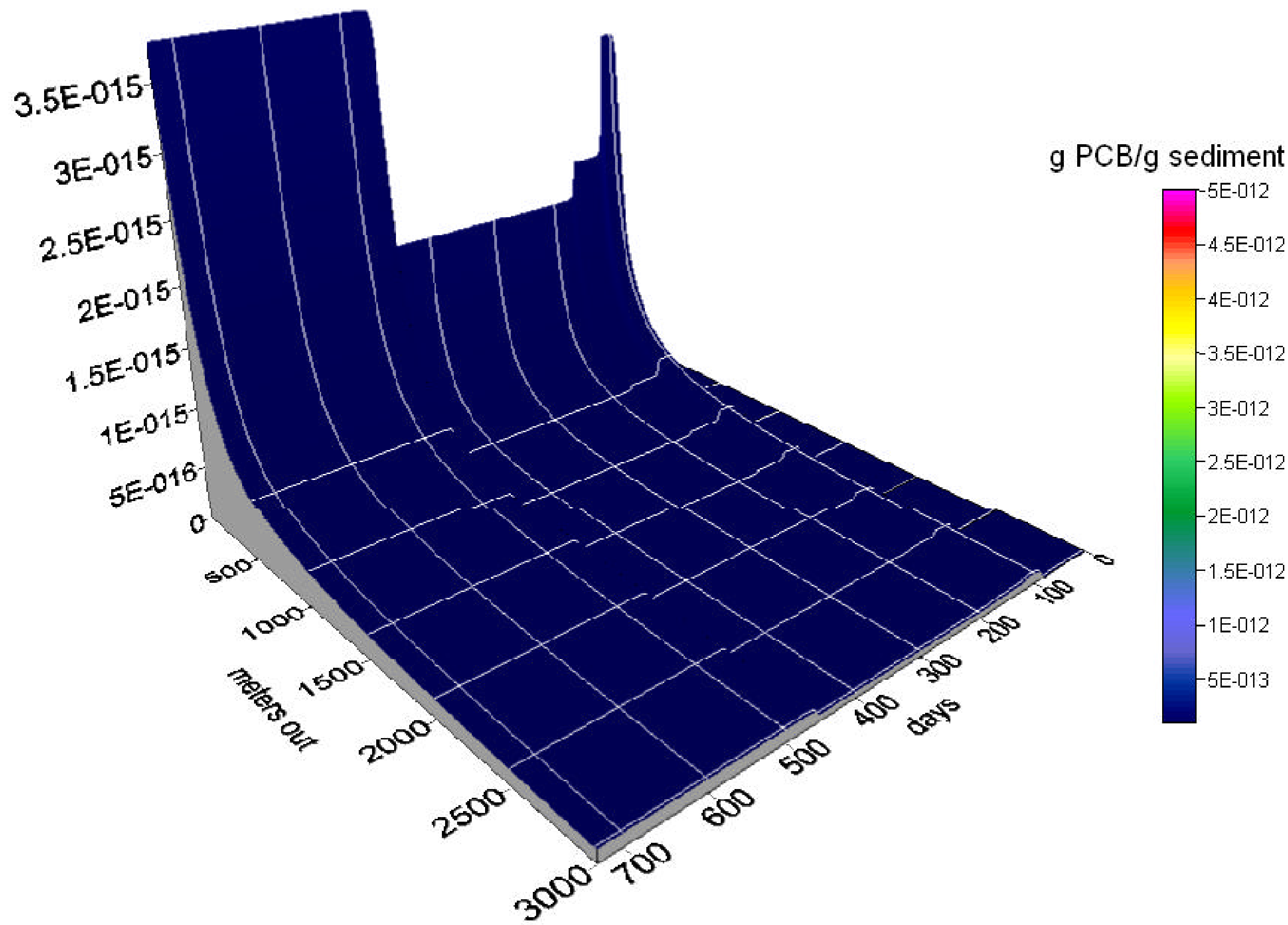


Figure B 41 - Total PCB in Water above Pycnocline

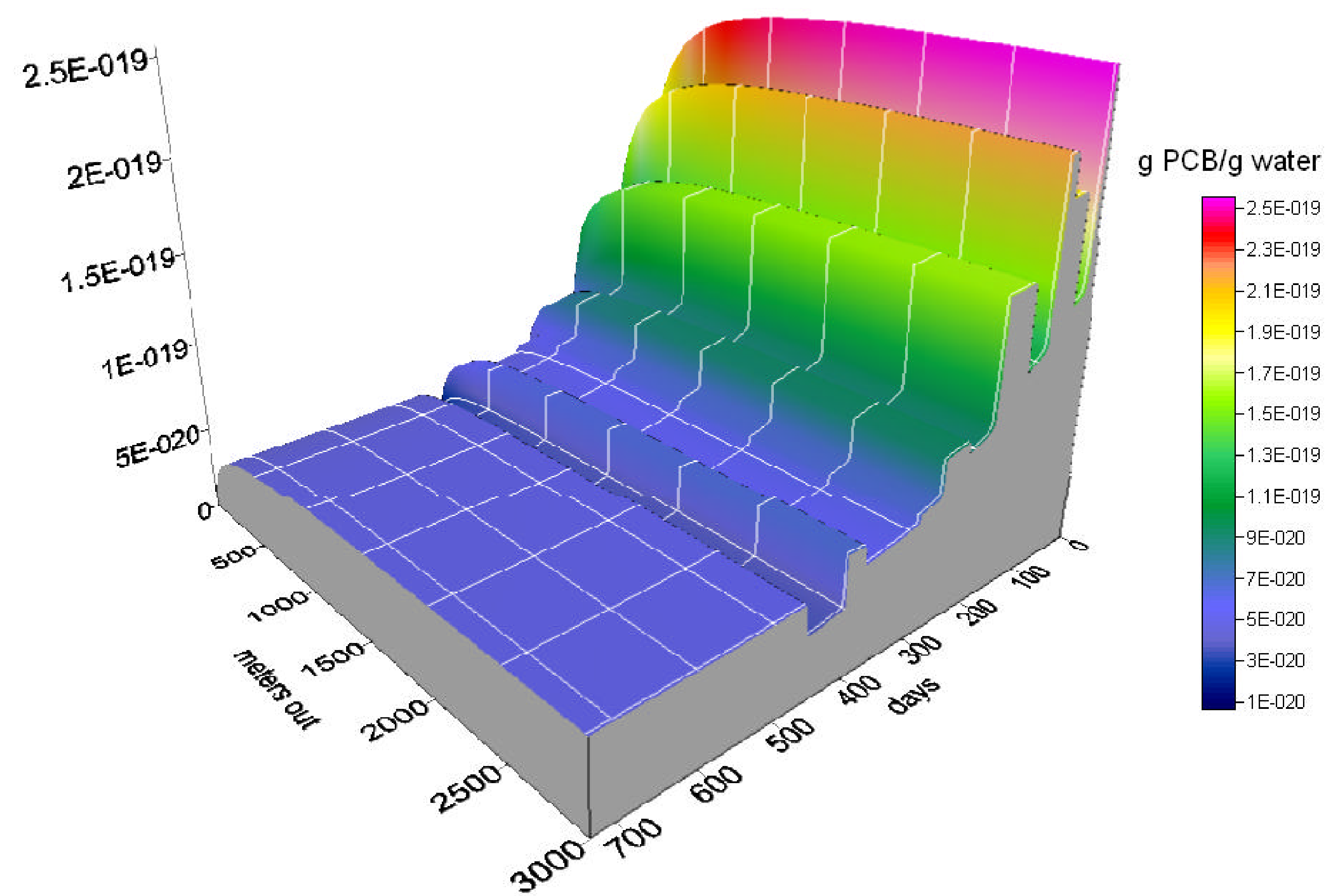


Figure B 42 - Monochlorobiphenyl in Water above Pycnocline

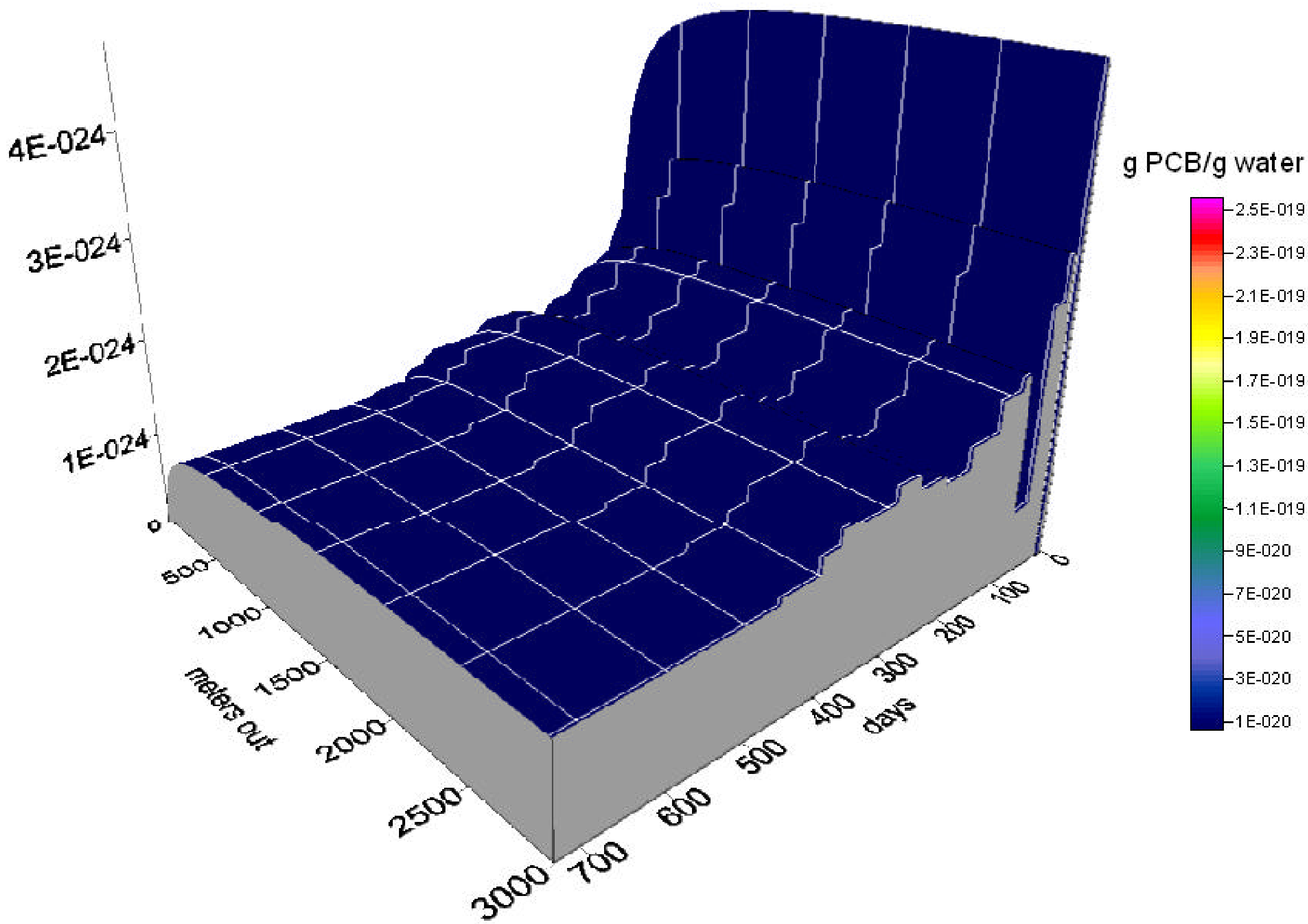


Figure B 43 - Dichlorobiphenyl in Water above Pycnocline

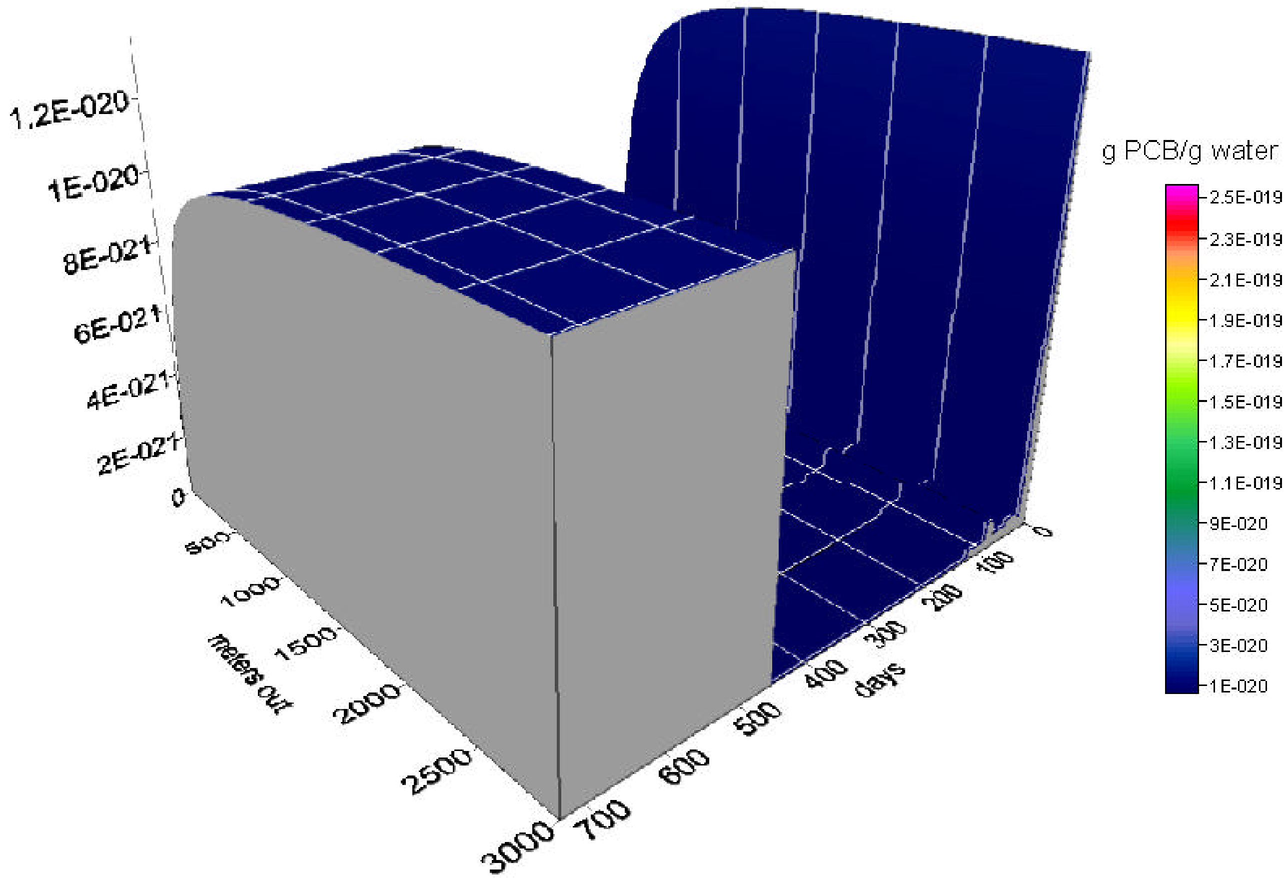


Figure B 44 - Trichlorobiphenyl in Water above Pycnocline

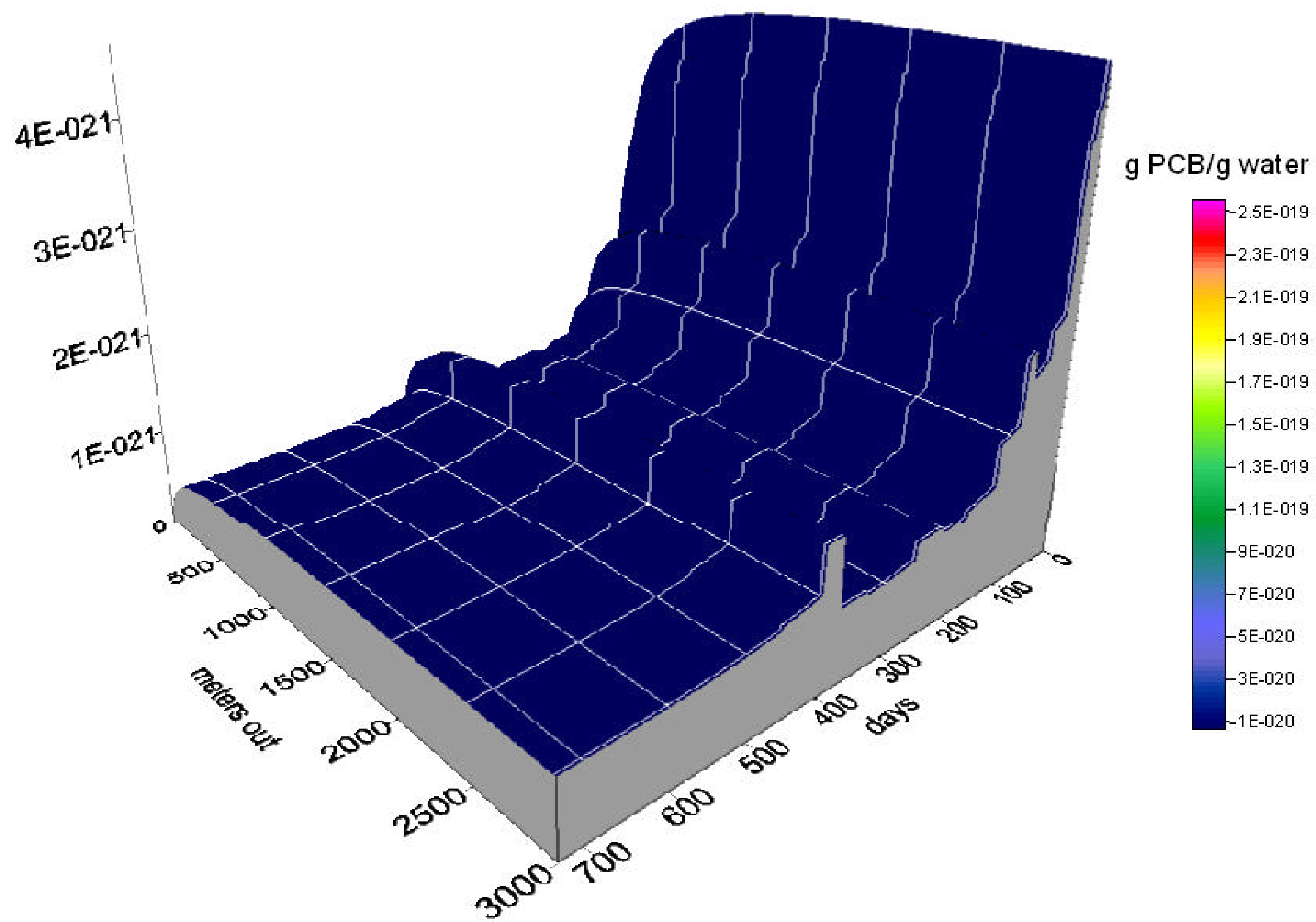


Figure B 45 - Tetrachlorobiphenyl in Water above Pycnocline

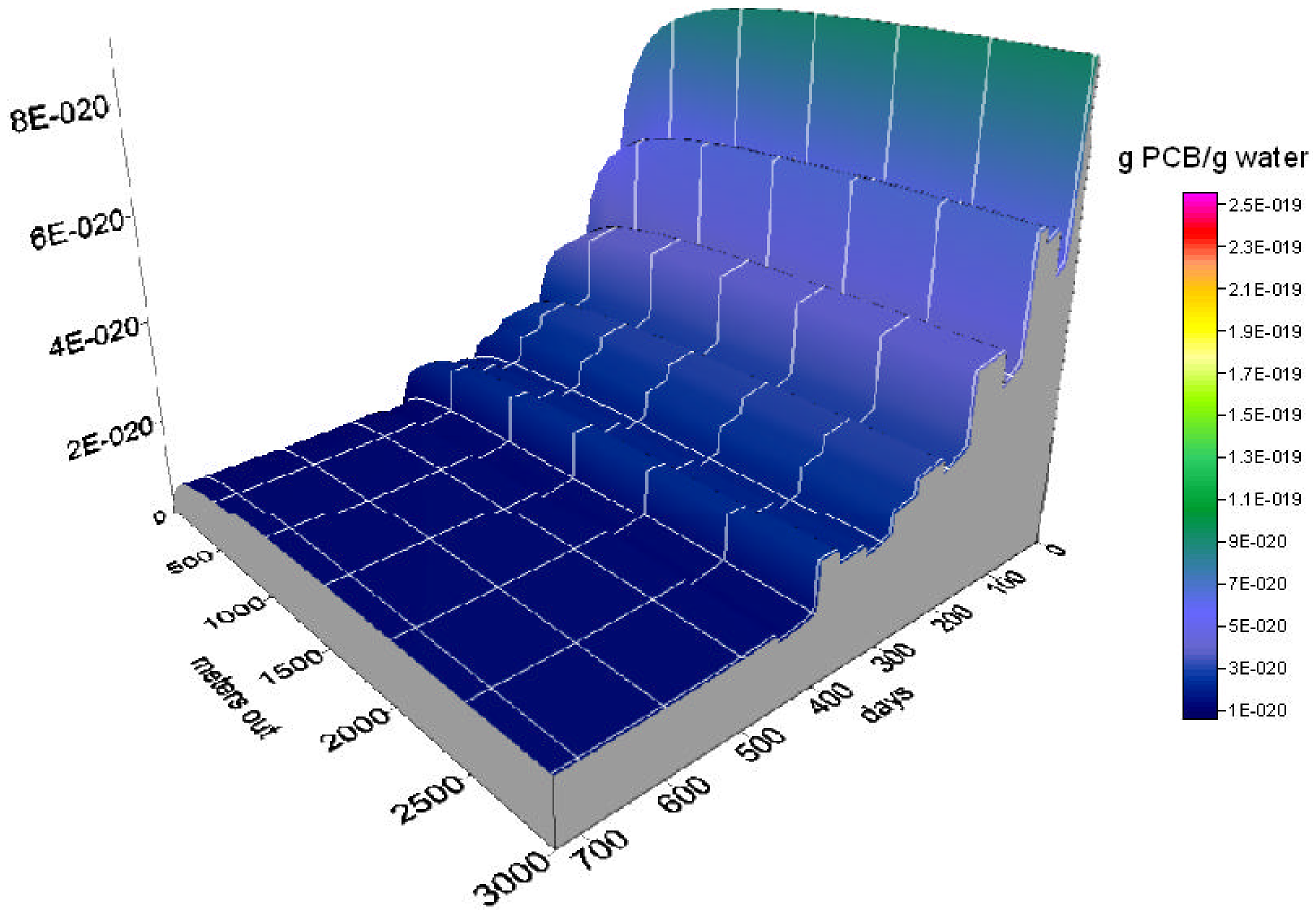


Figure B 46 – Pentachlorobiphenyl in Water above Pycnocline

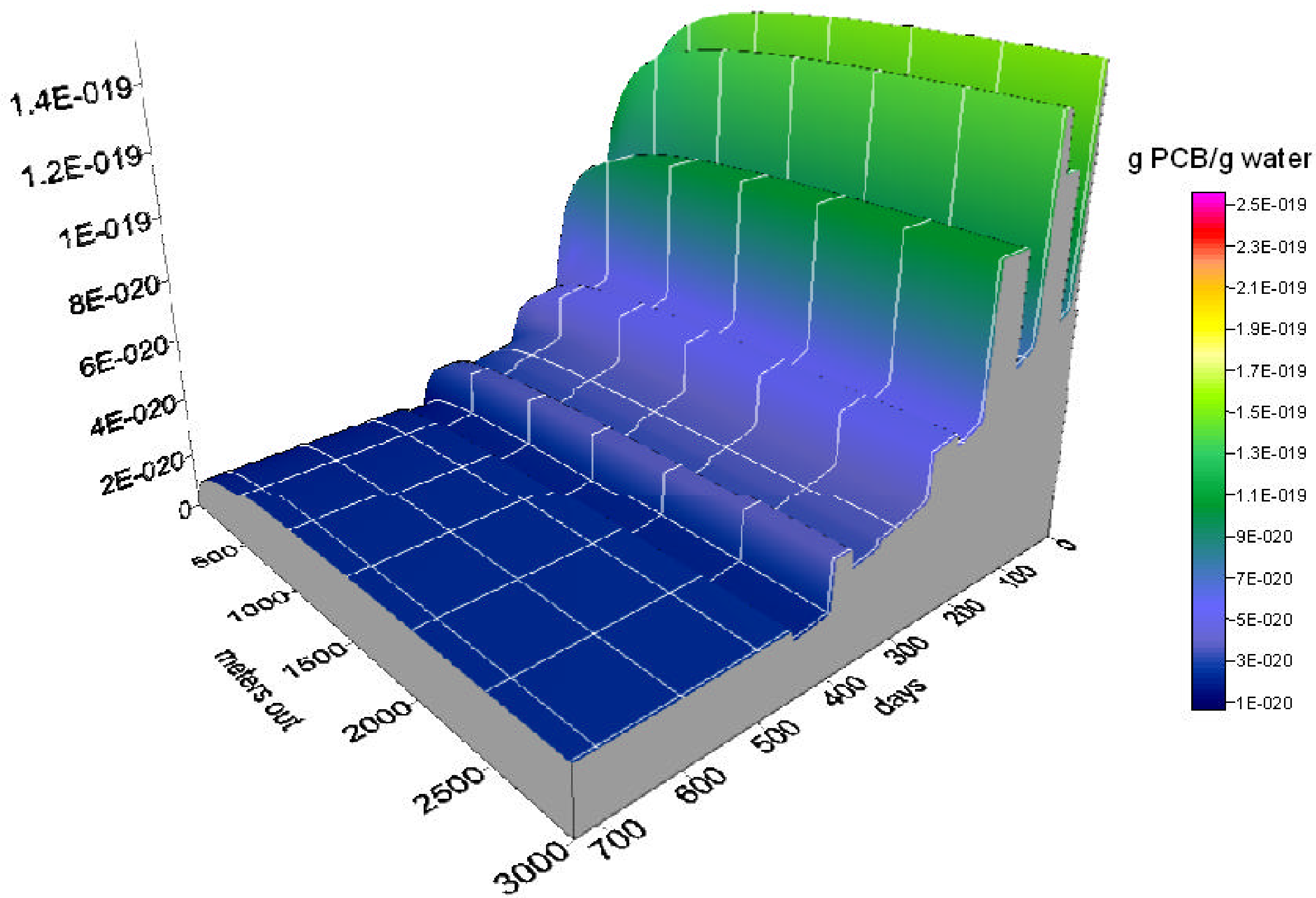


Figure B 47 - Hexachlorobiphenyl in Water above Pycnocline

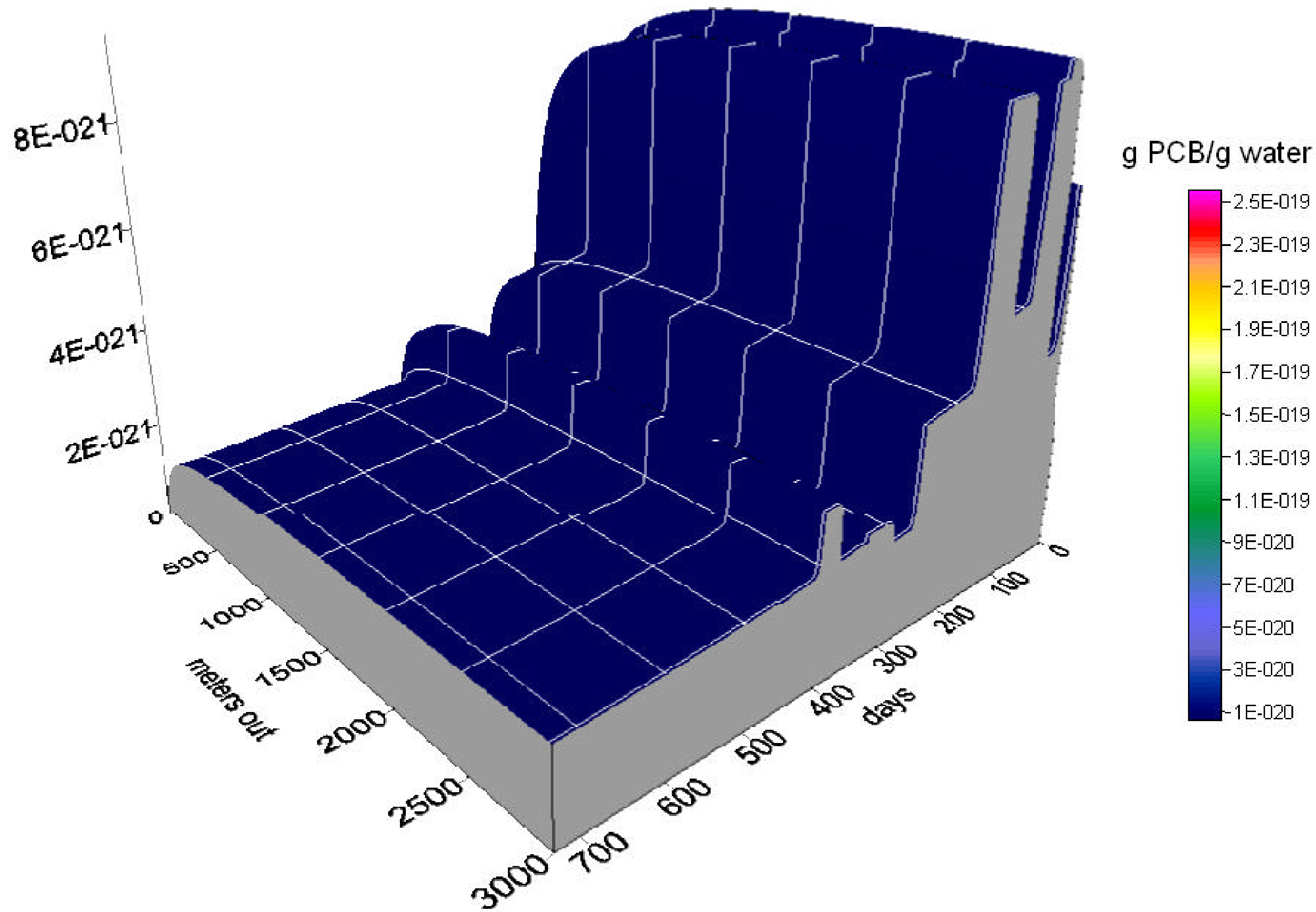


Figure B 48 - Heptachlorobiphenyl in Water above Pycnocline

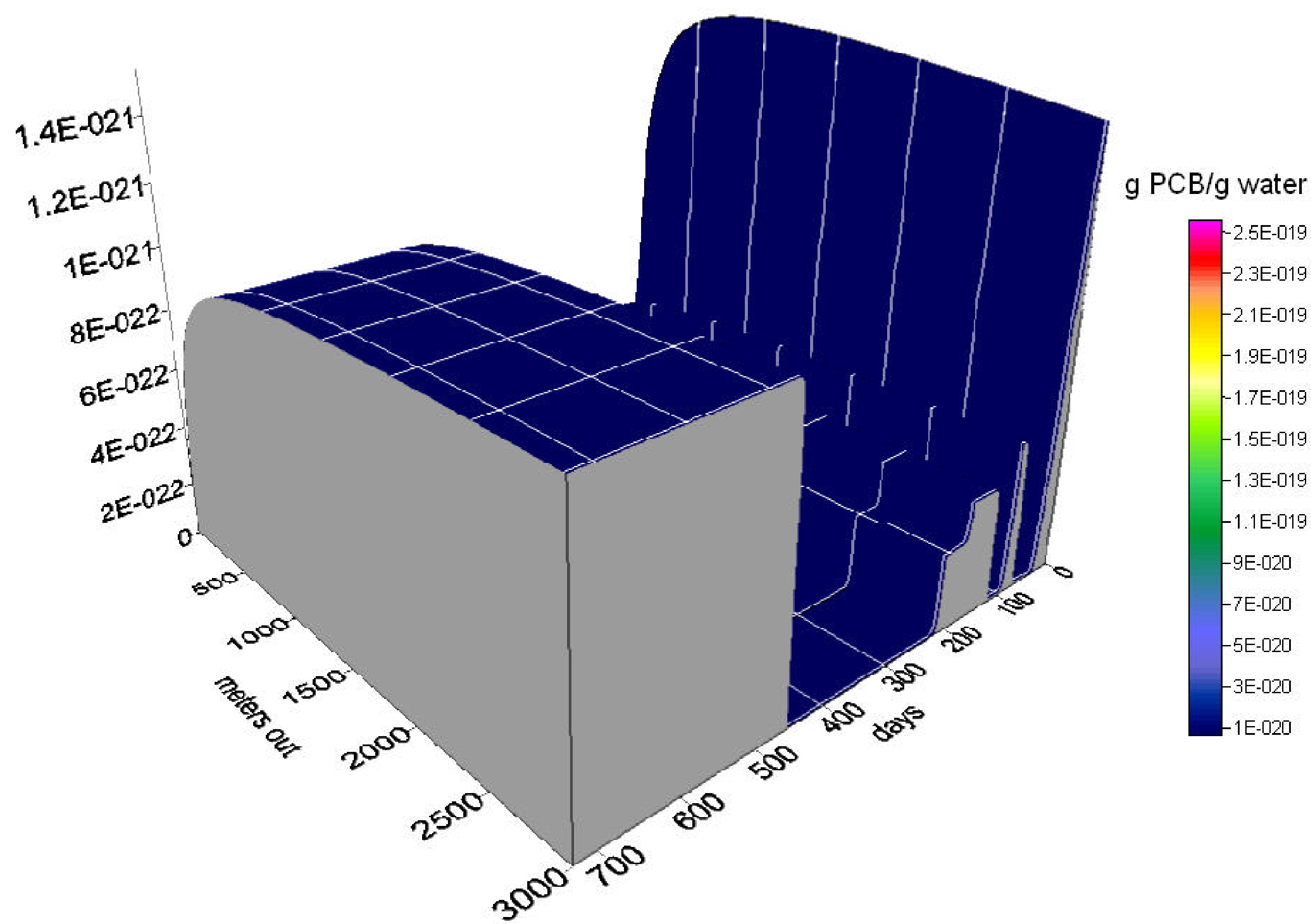


Figure B 49 - Nonachlorobiphenyl in Water above Pycnocline

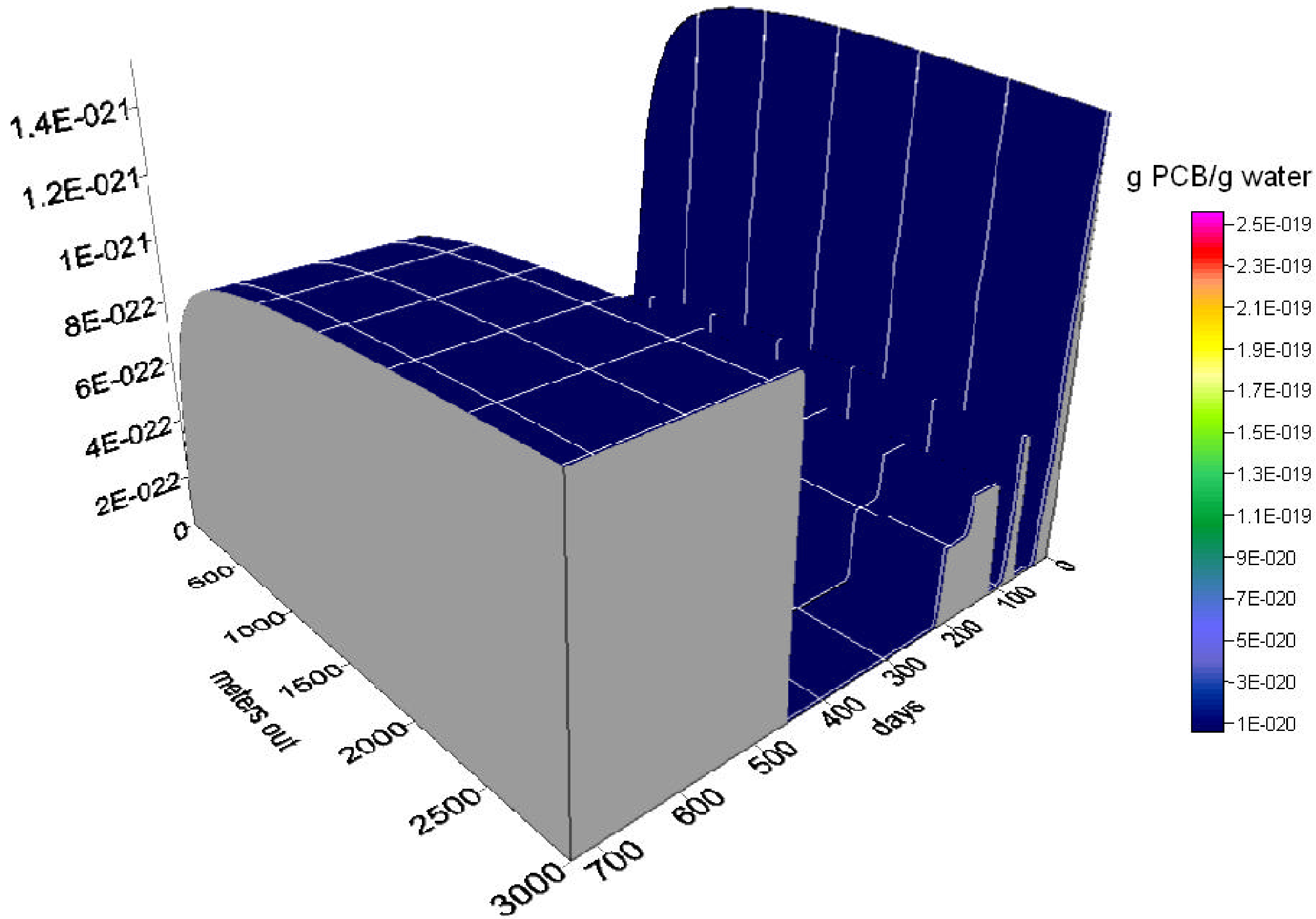


Figure B 50 - Decachlorobiphenyl in Water above Pycnocline

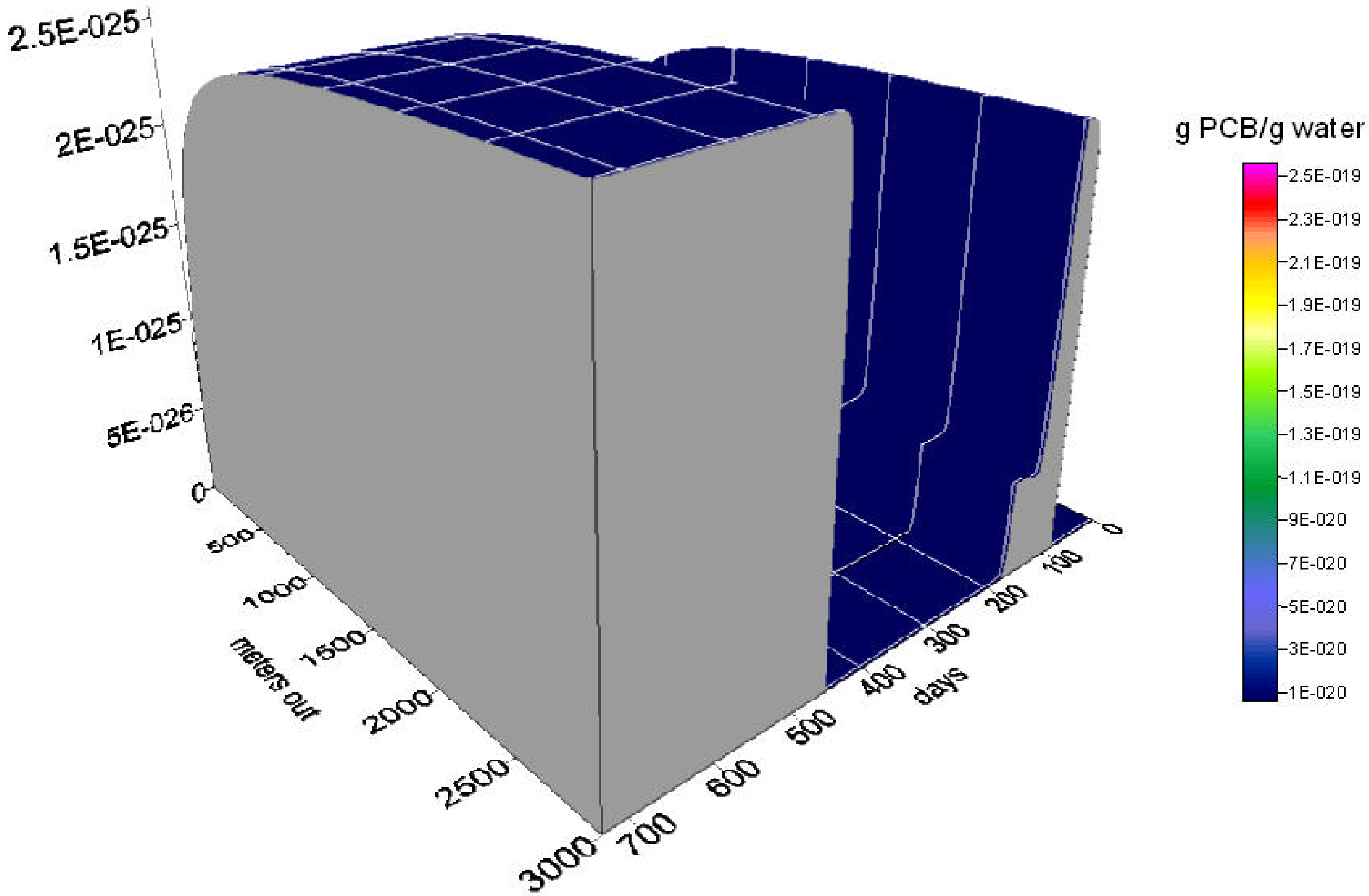


Figure B 51 - Total PCB in DOC above Pycnocline

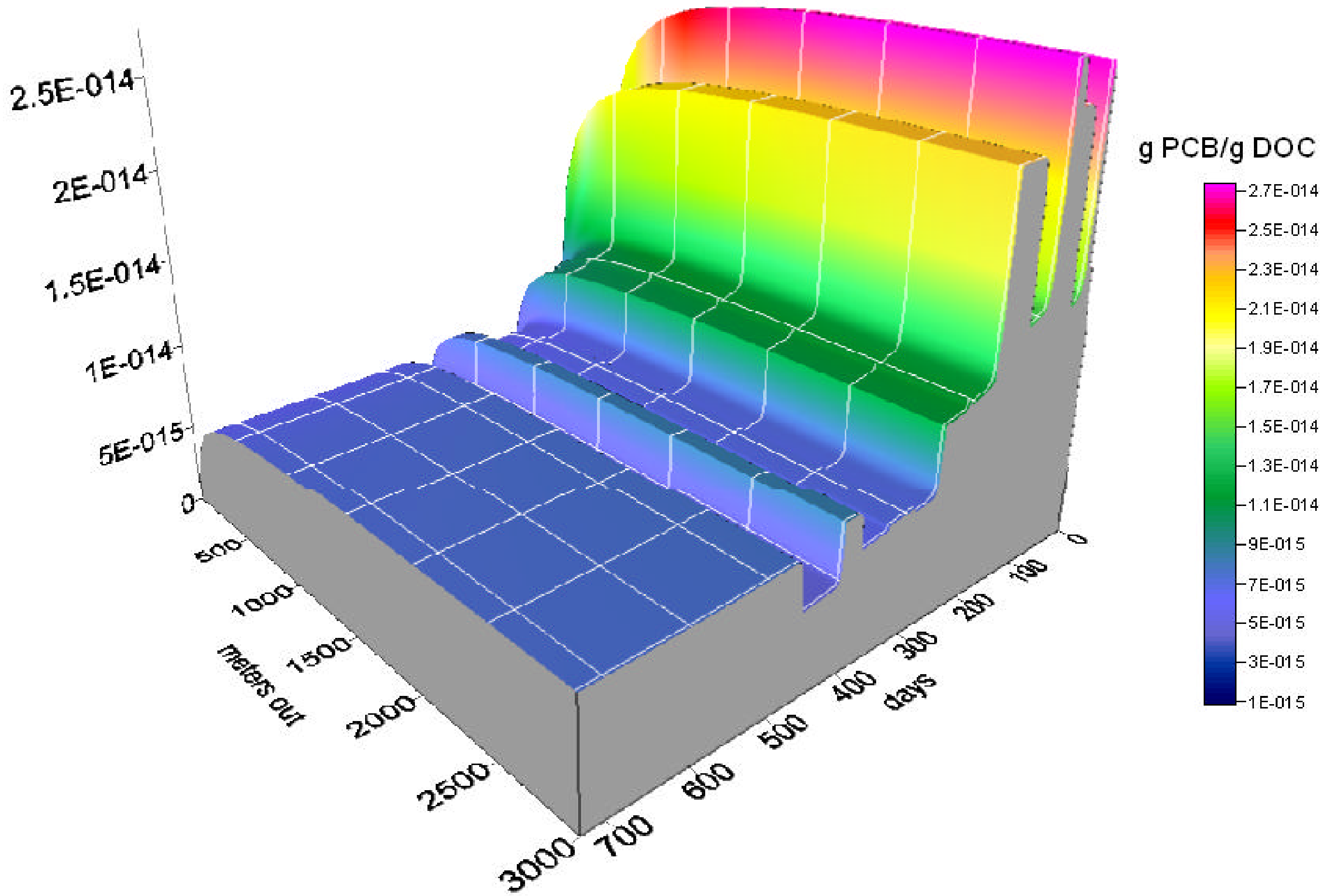


Figure B 52 - Monochlorobiphenyl in DOC above Pycnocline

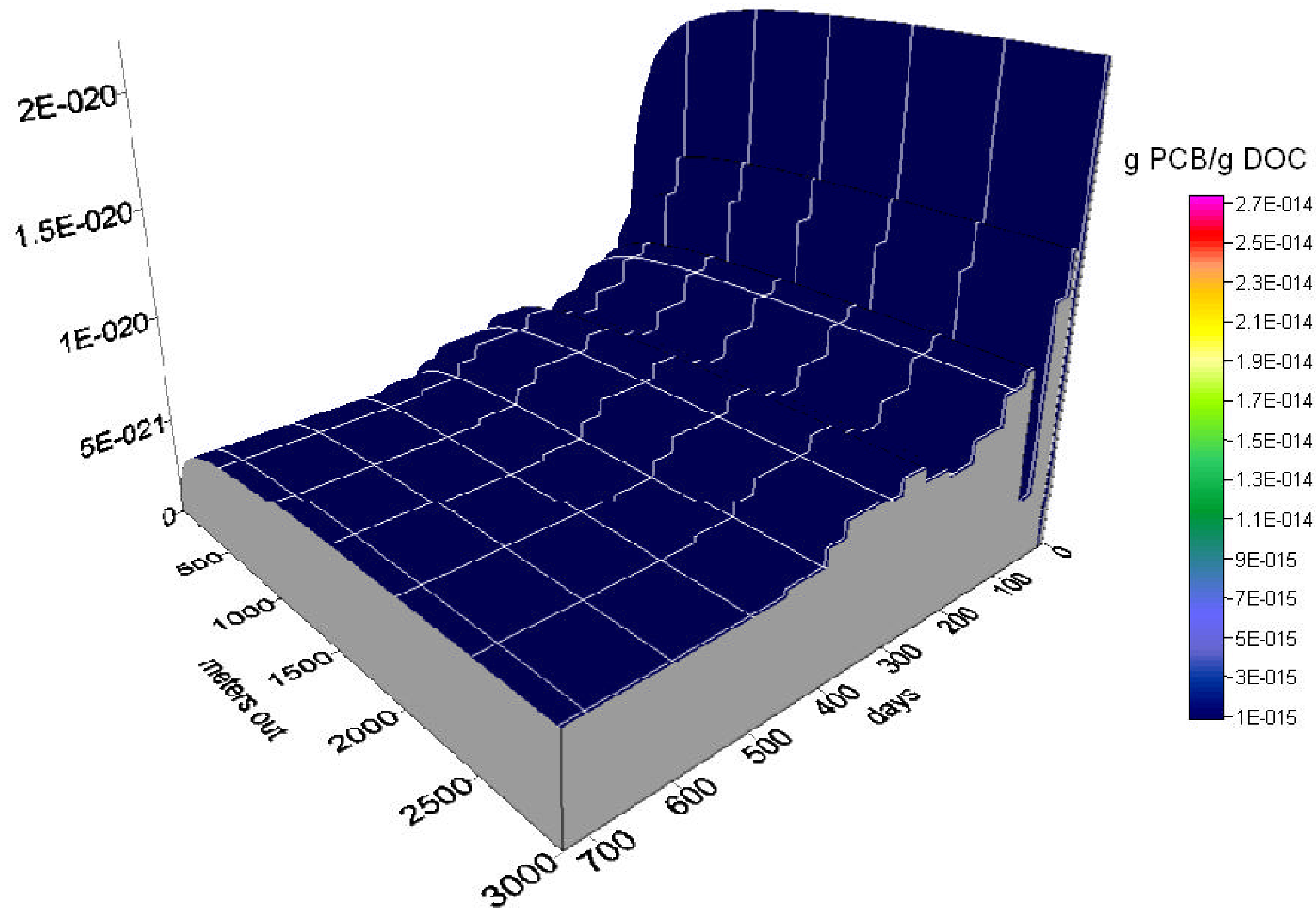


Figure B 53 – Dichlorobiphenyl in DOC above Pycnocline

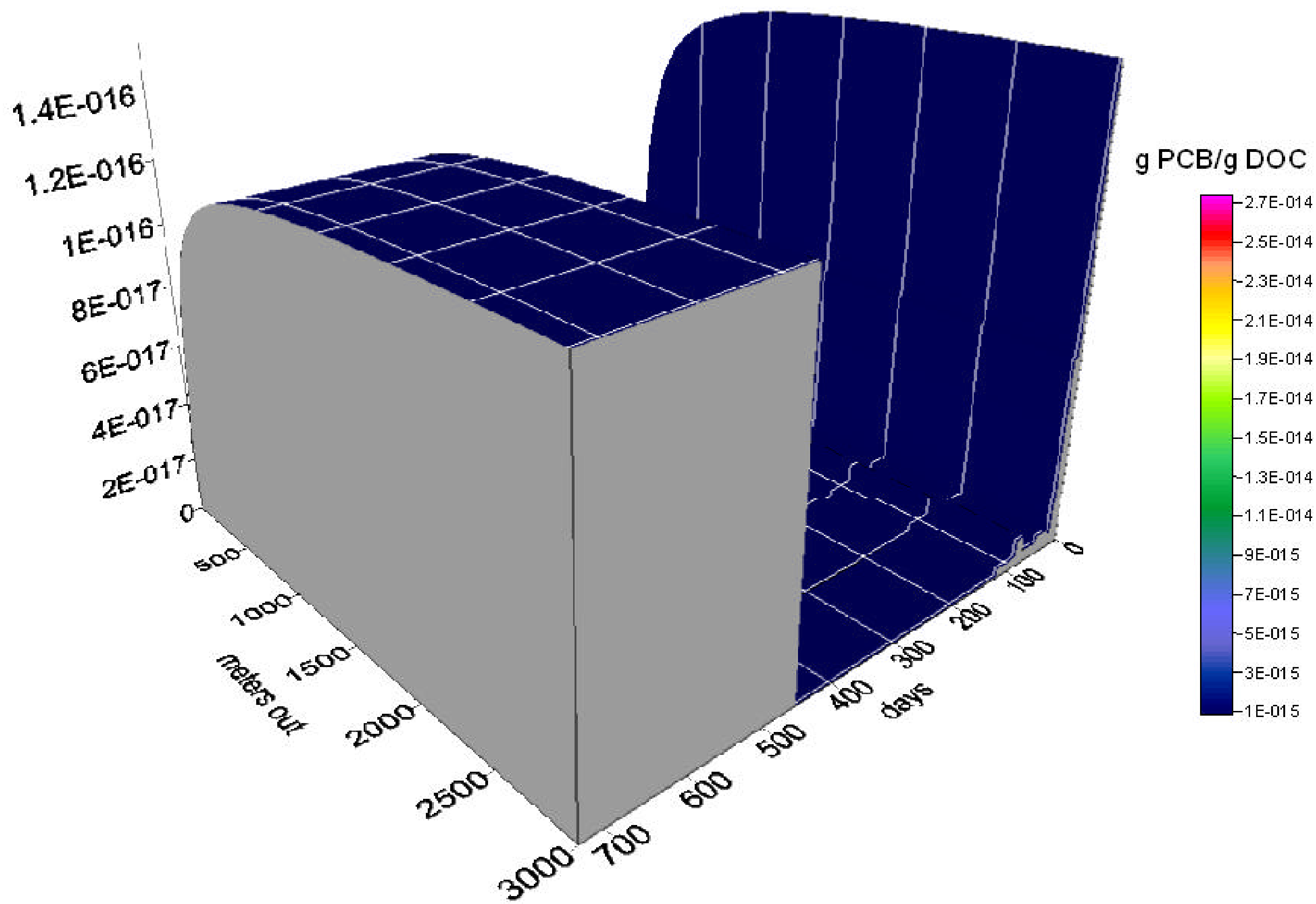


Figure B 54 - Trichlorobiphenyl in DOC above Pycnocline

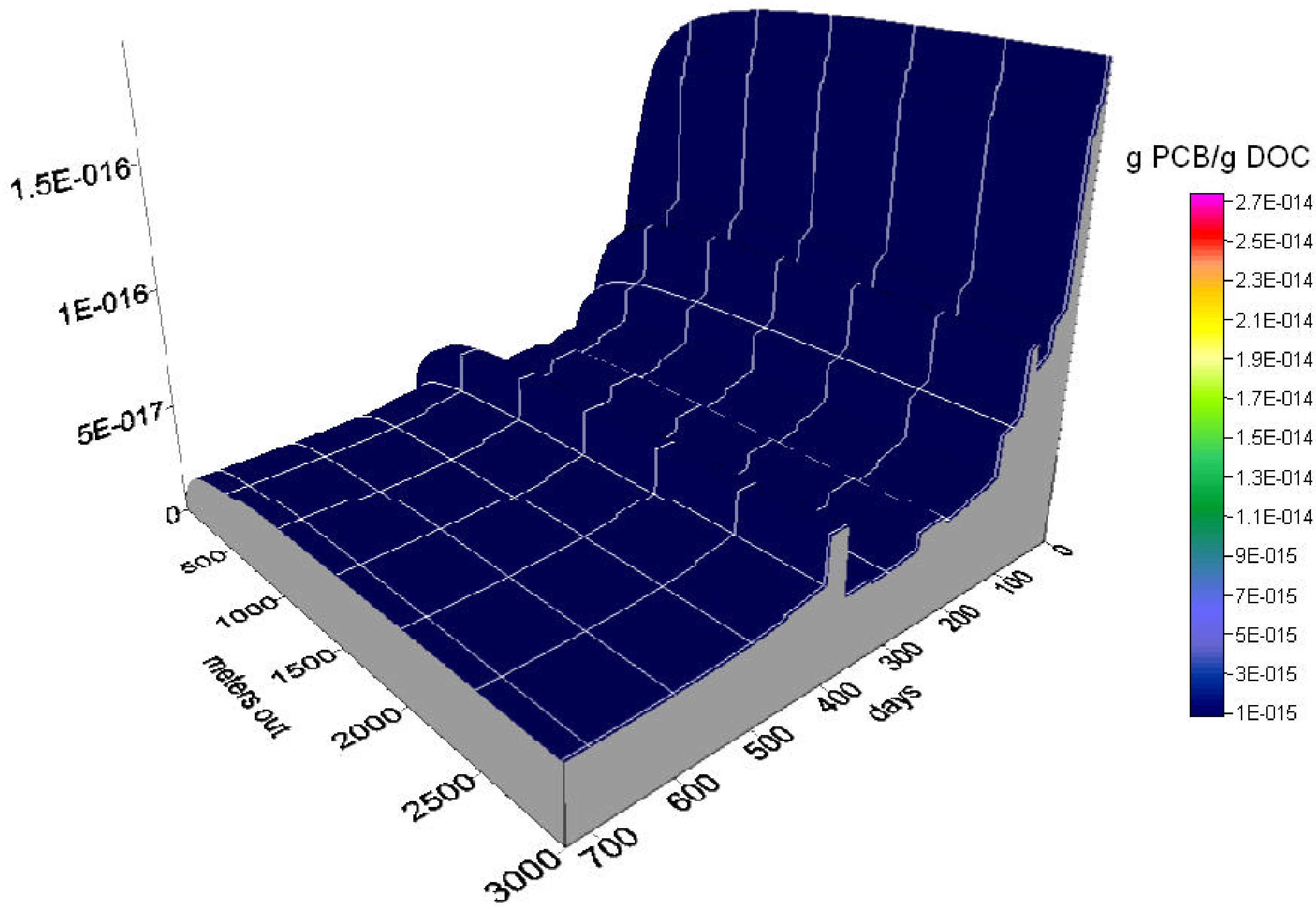


Figure B 55 - Tetrachlorobiphenyl in DOC above Pycnocline

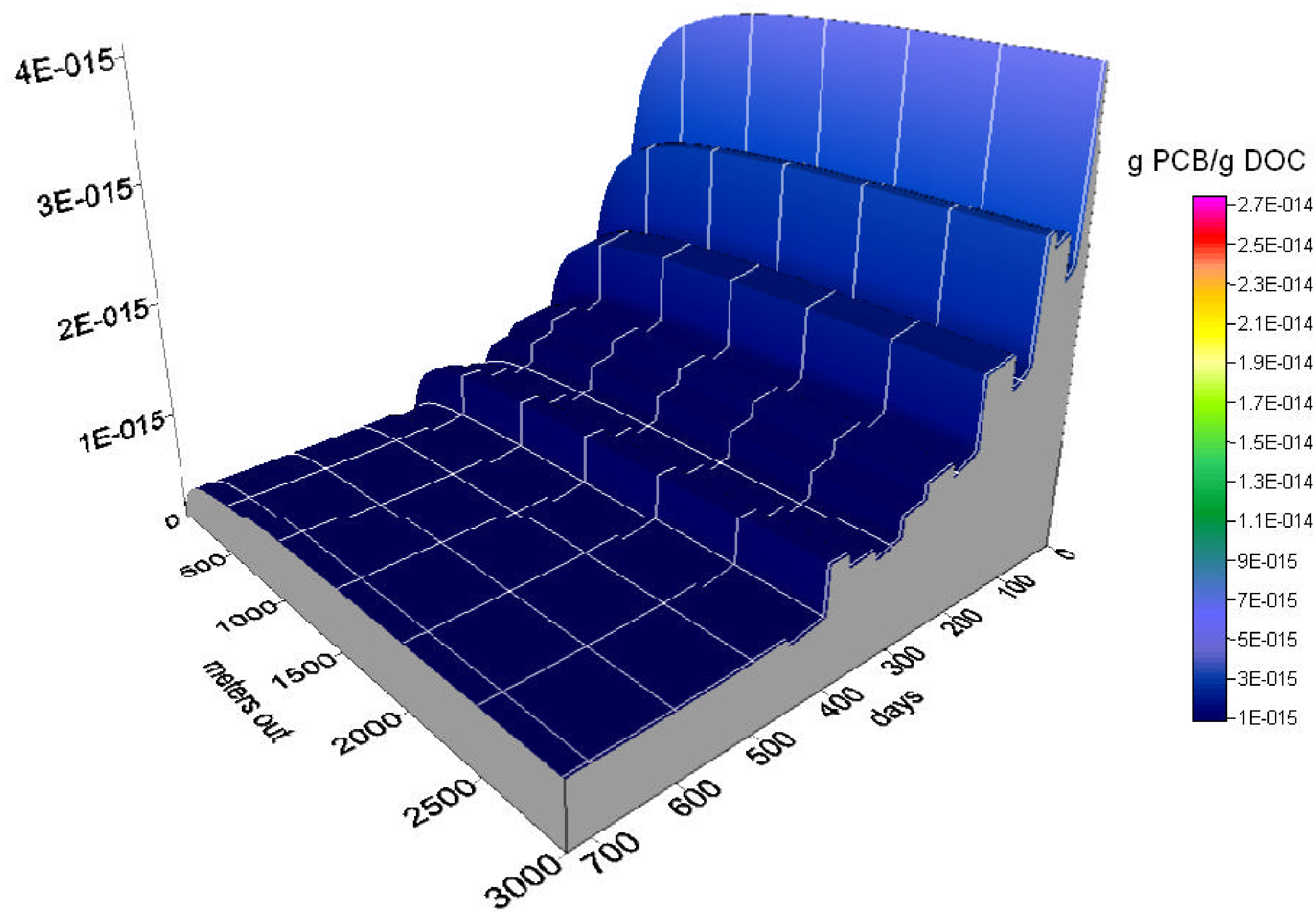


Figure B 56 - Pentachlorobiphenyl in DOC above Pycnocline

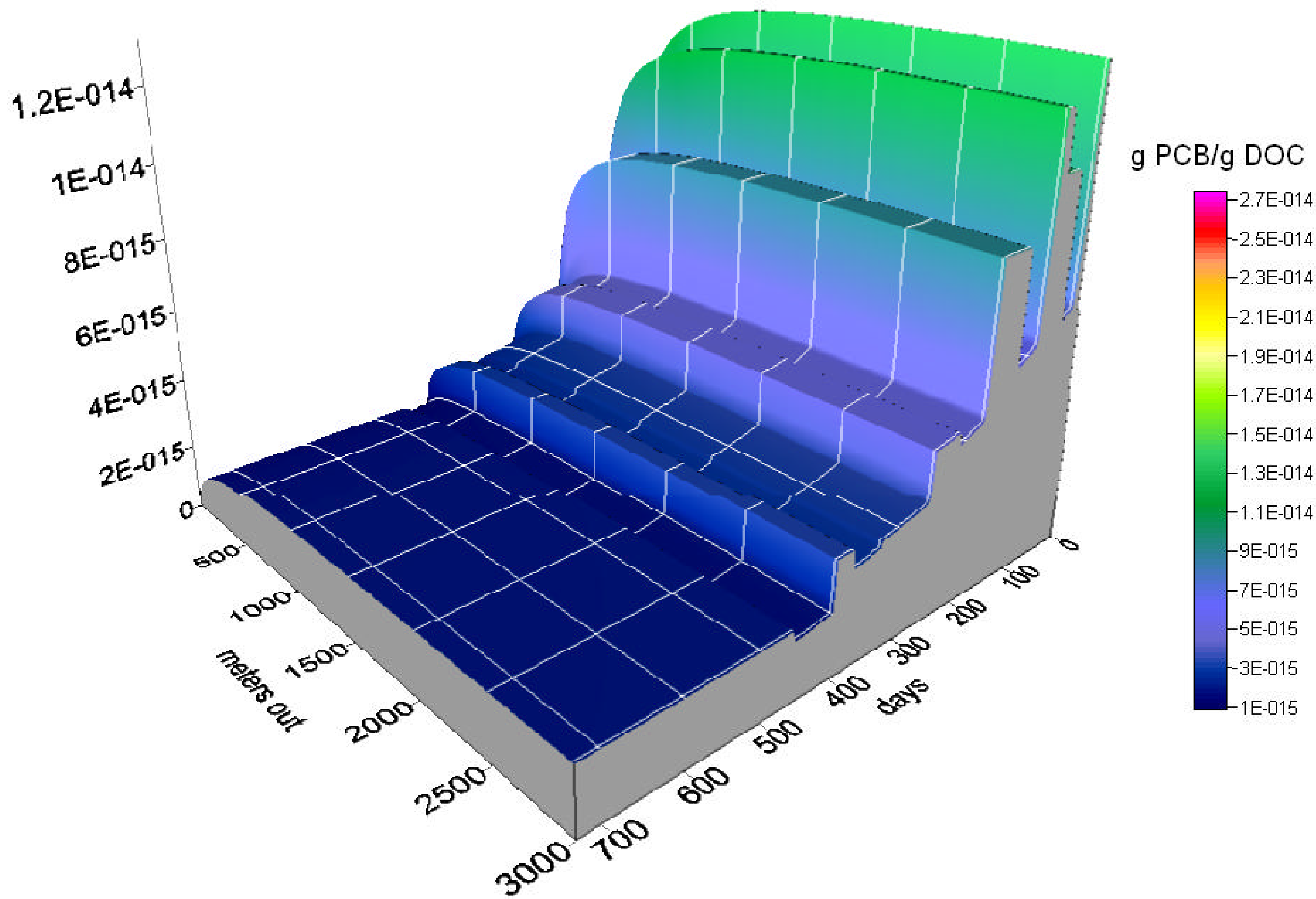


Figure B 57 - Hexachlorobiphenyl in DOC above Pycnocline

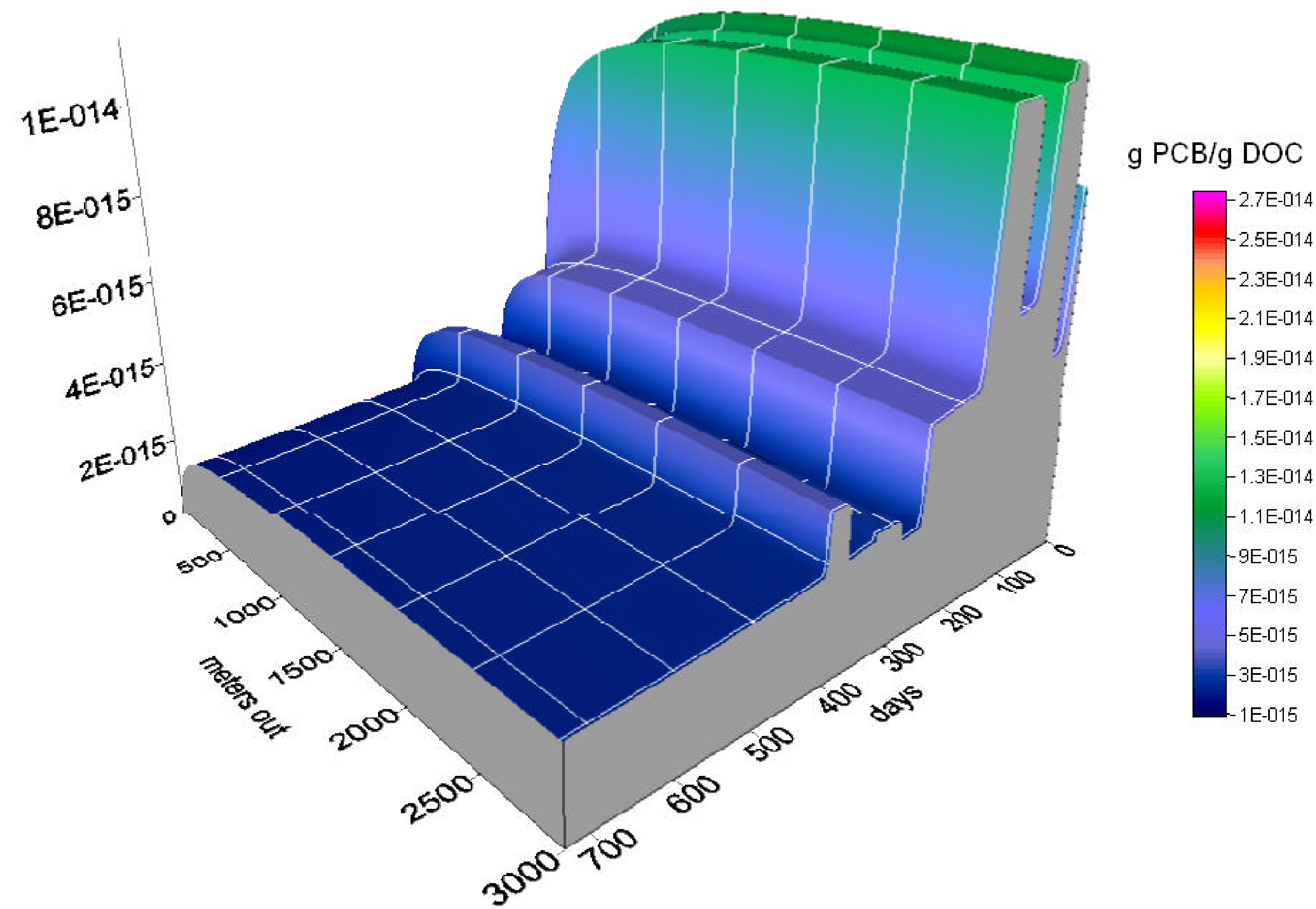


Figure B 58 - Heptachlorobiphenyl in DOC above Pycnocline

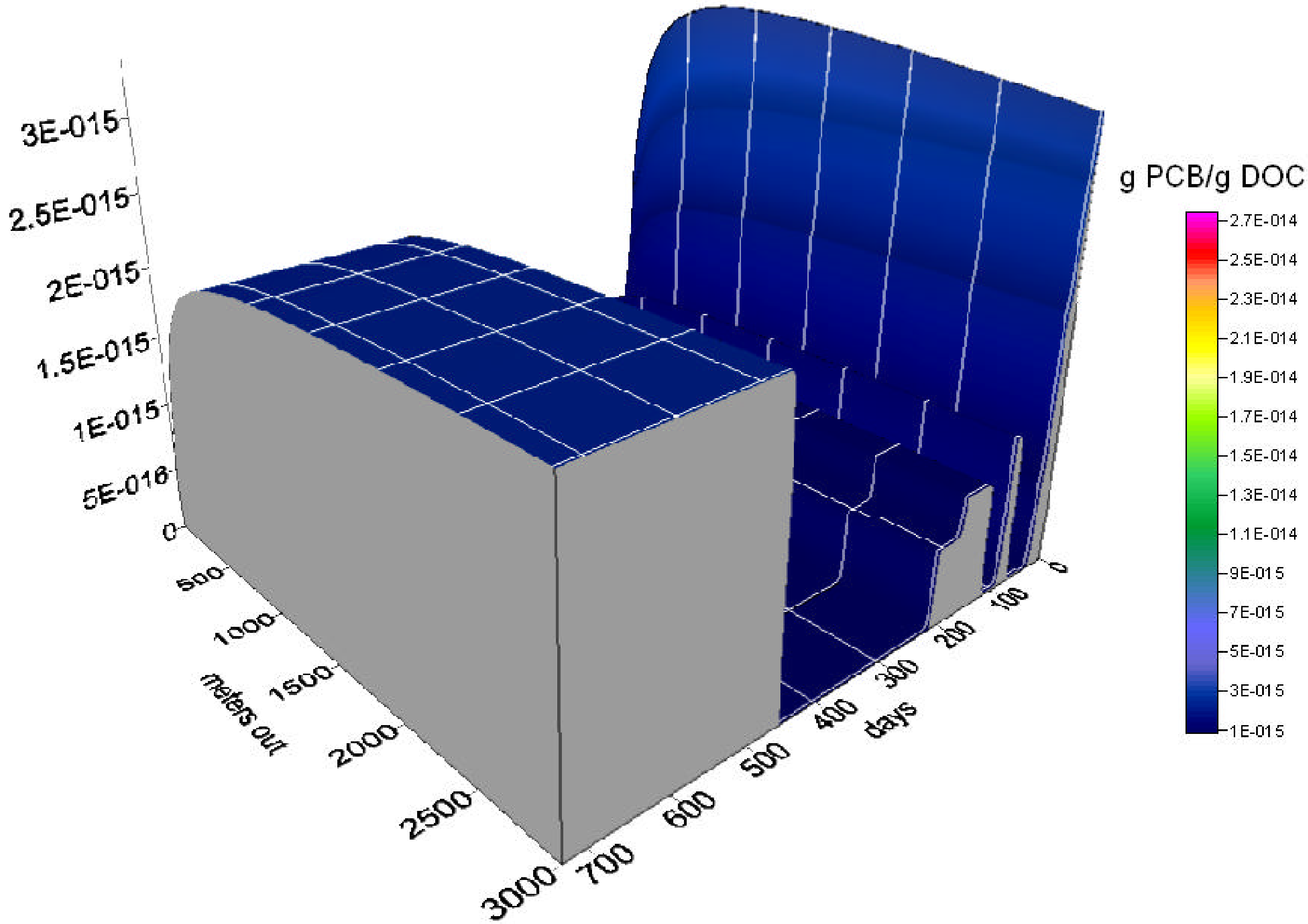


Figure B 59 – Nonachlorobiphenyl in DOC above Pycnocline

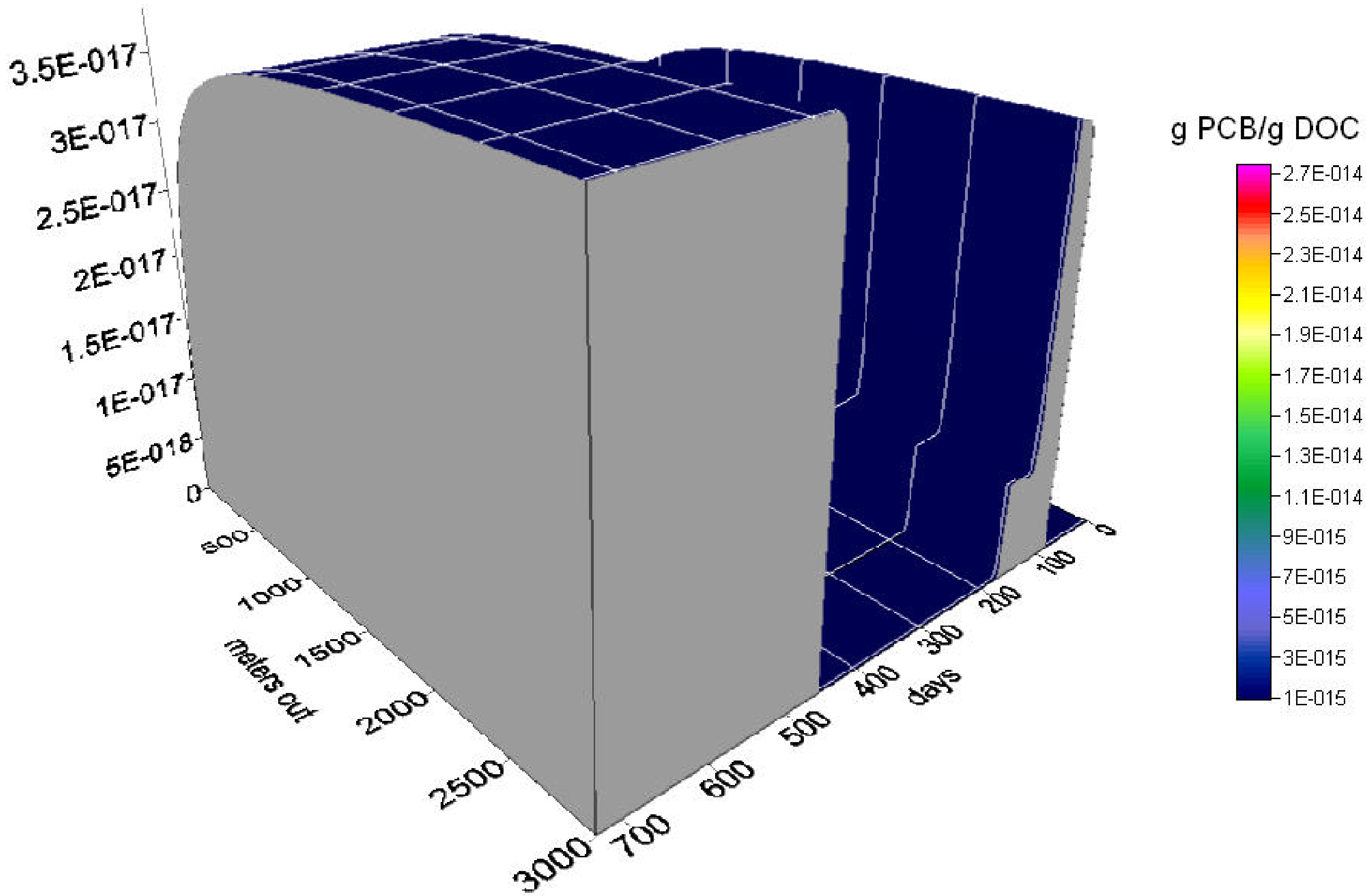


Figure B 60 - Decachlorobiphenyl in DOC above Pycnocline

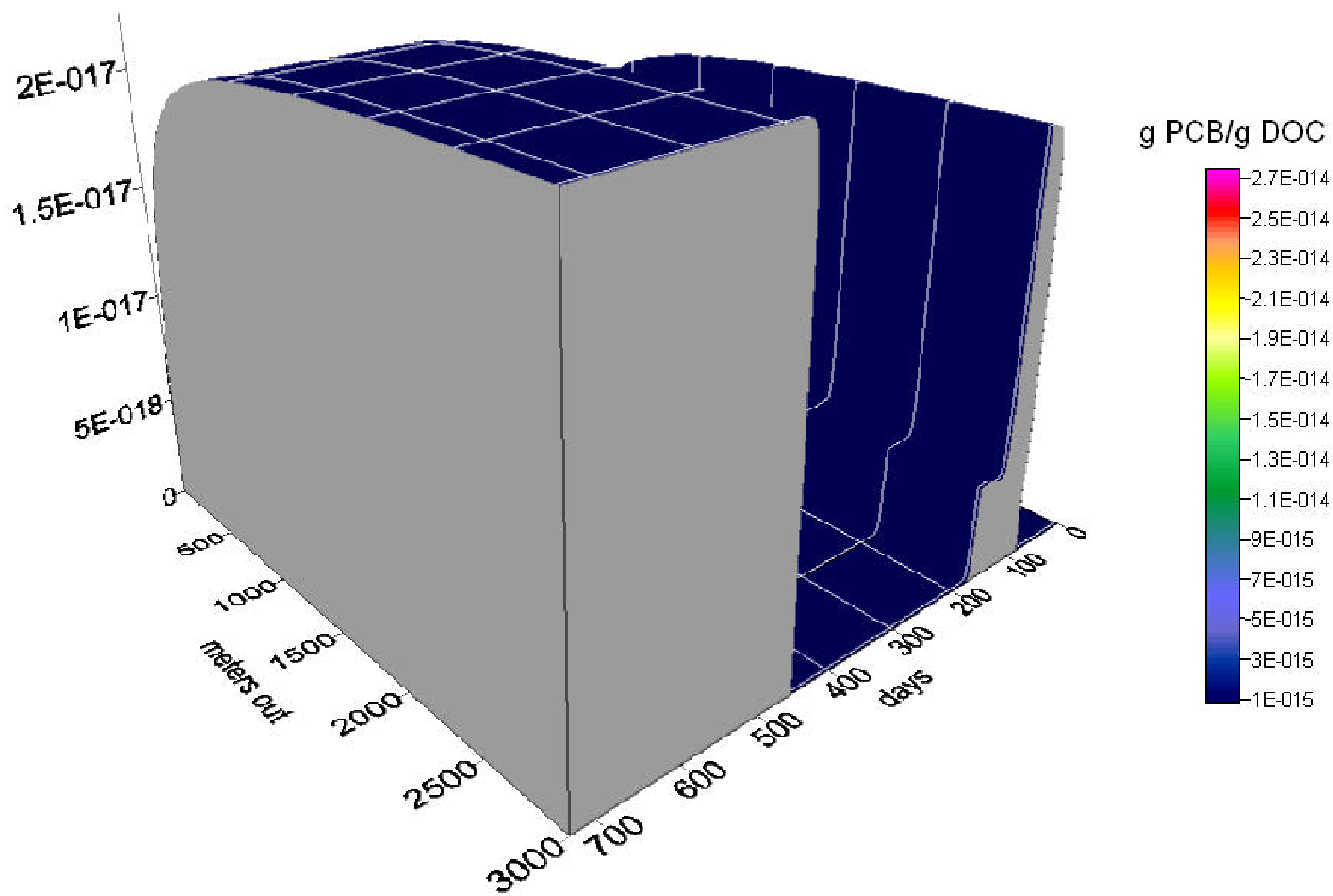


Figure B 61 - Total PCB in TSS above Pycnocline

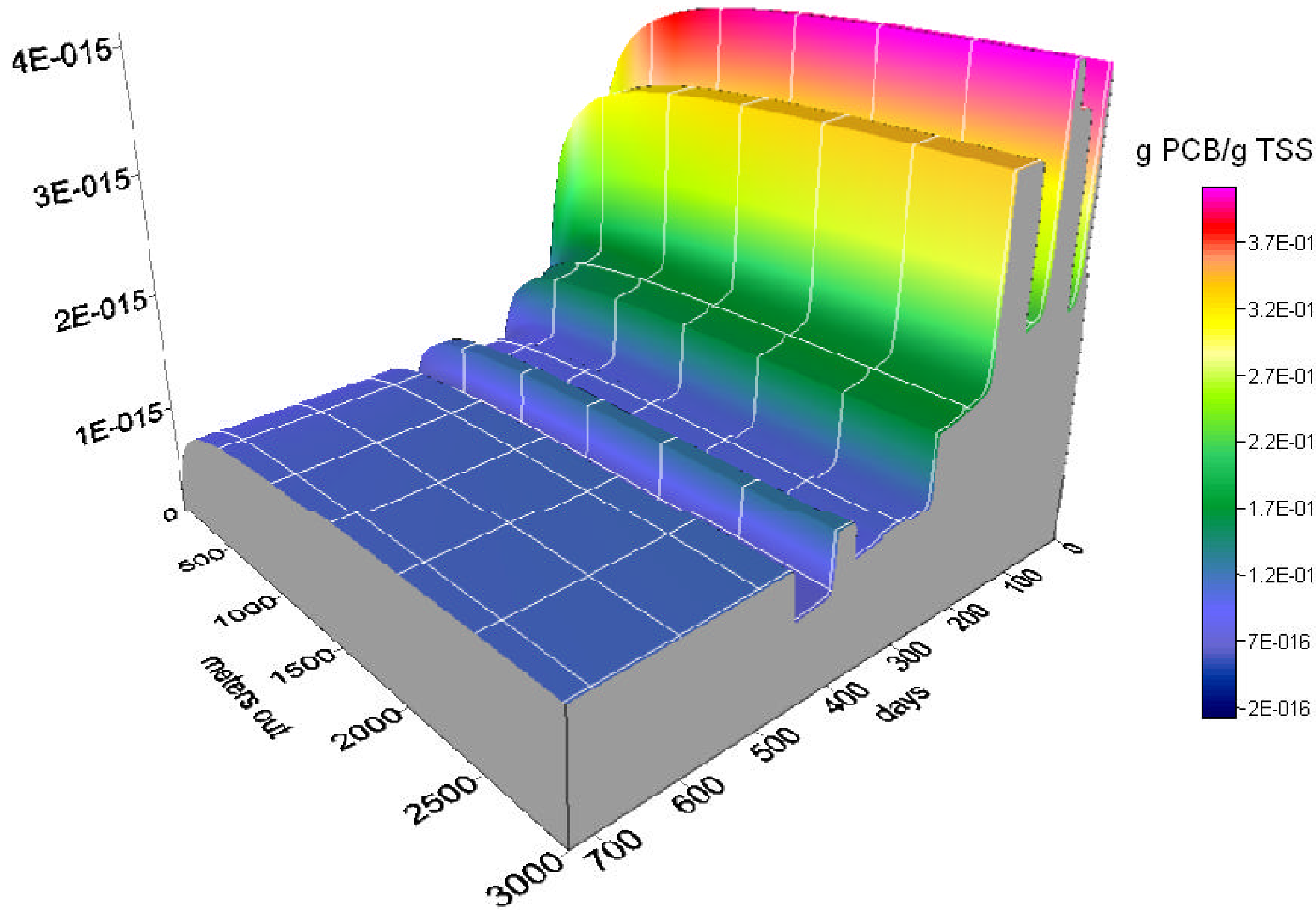


Figure B 62 - Monochlorobiphenyl in TSS above Pycnocline

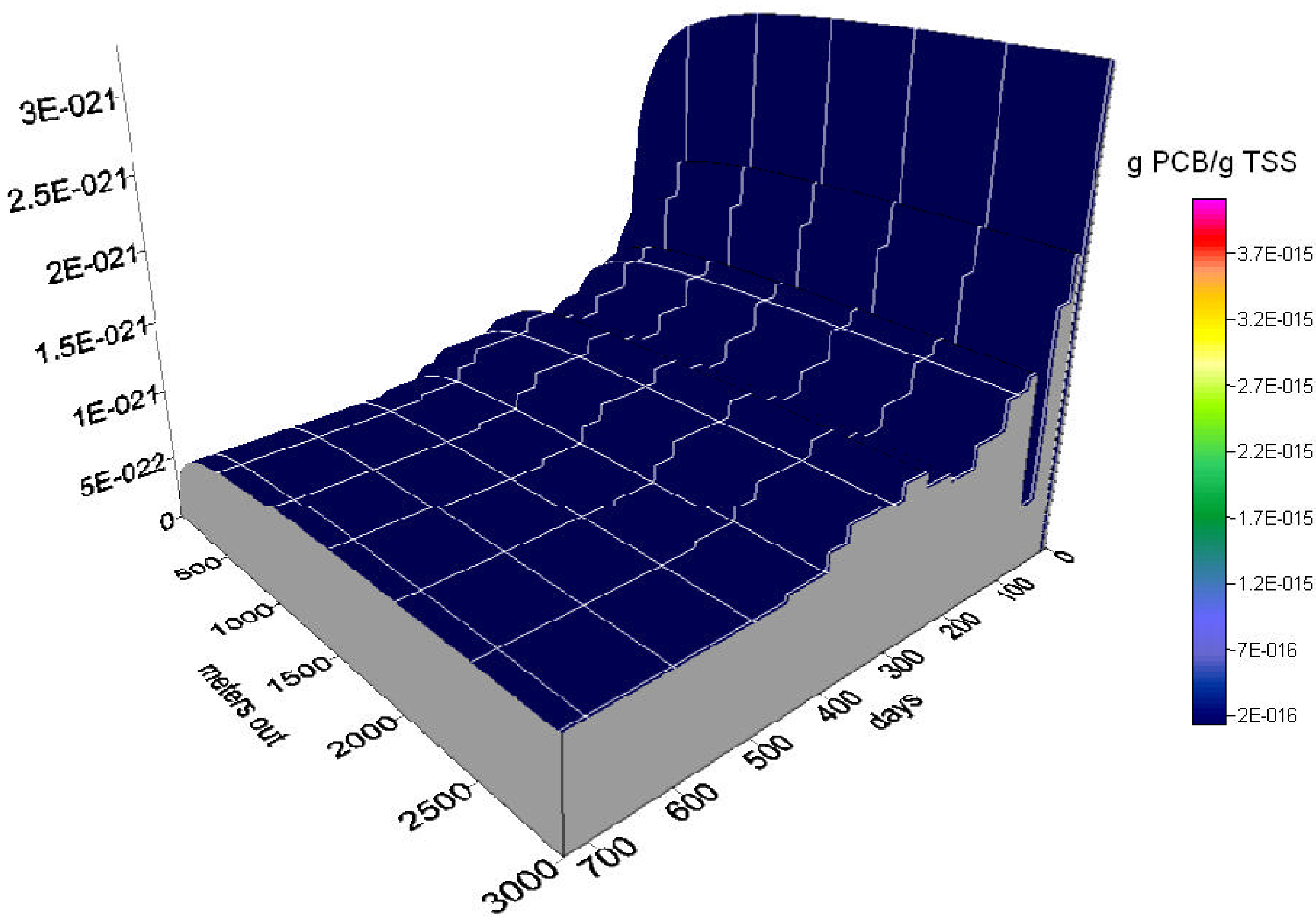


Figure B 63 - Dichlorobiphenyl in TSS above pycnocline

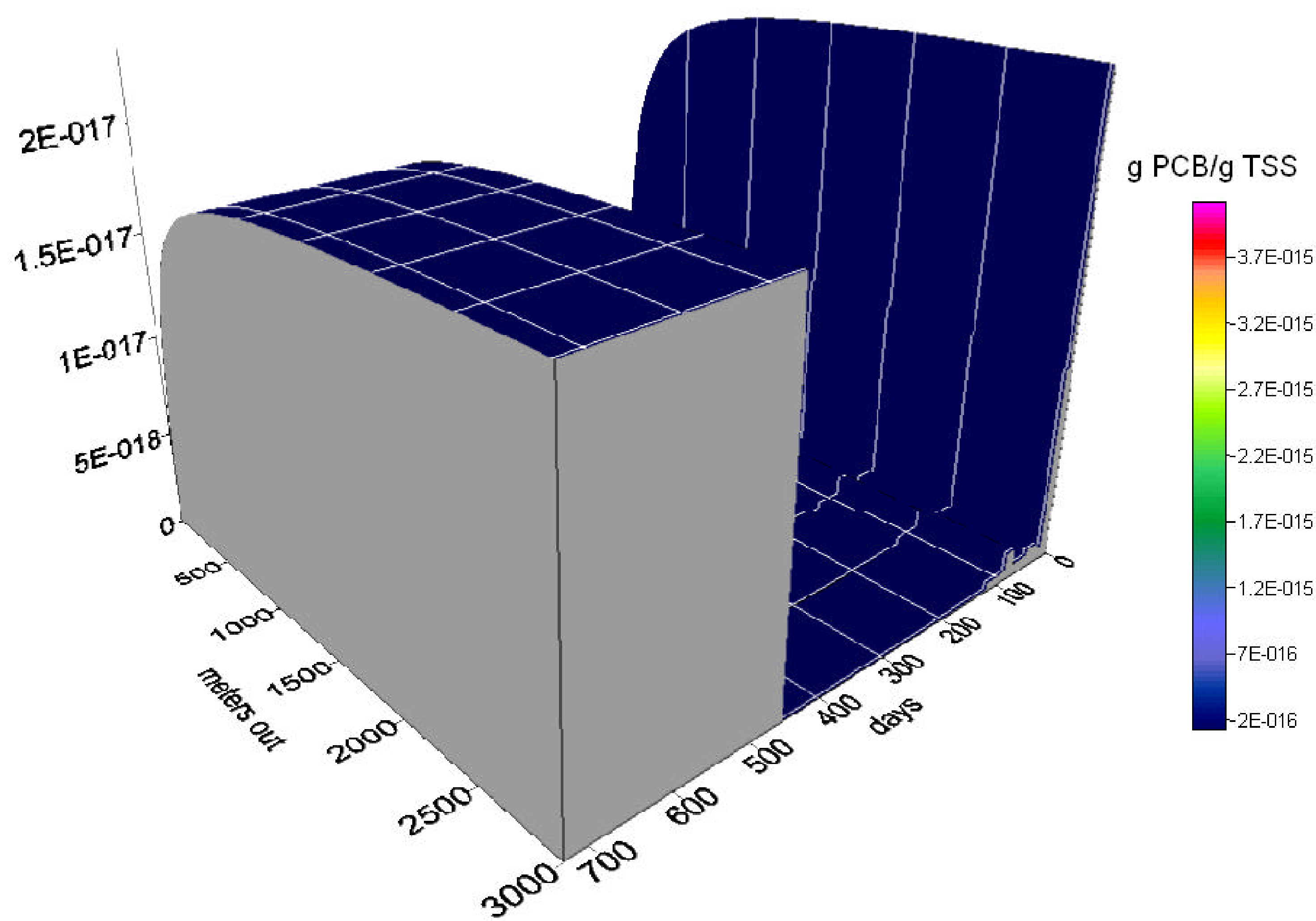


Figure B 64 - Trichlorobiphenyl in TSS above Pycnocline

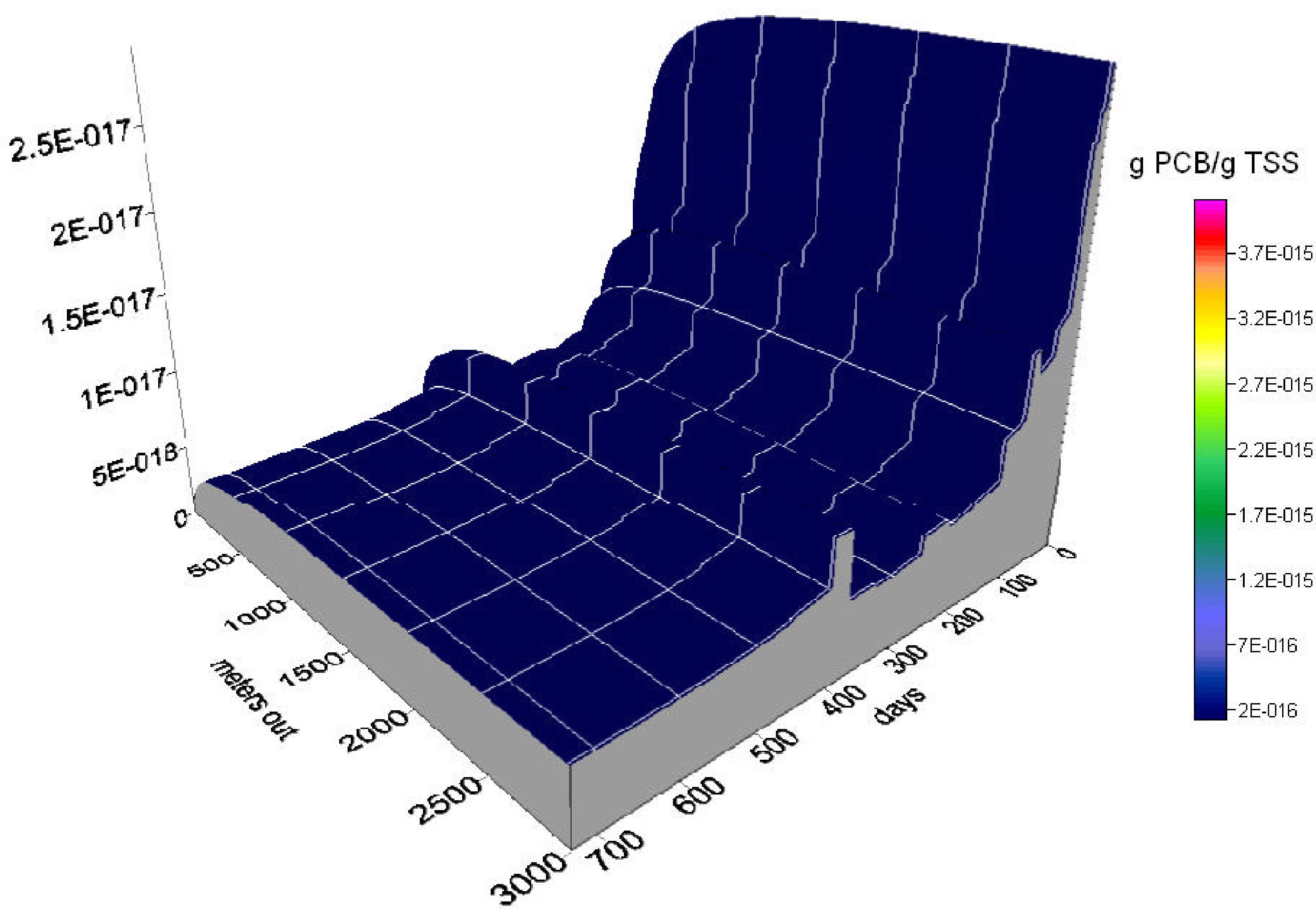


Figure B 65 - Tetrachlorobiphenyl in TSS above Pycnocline

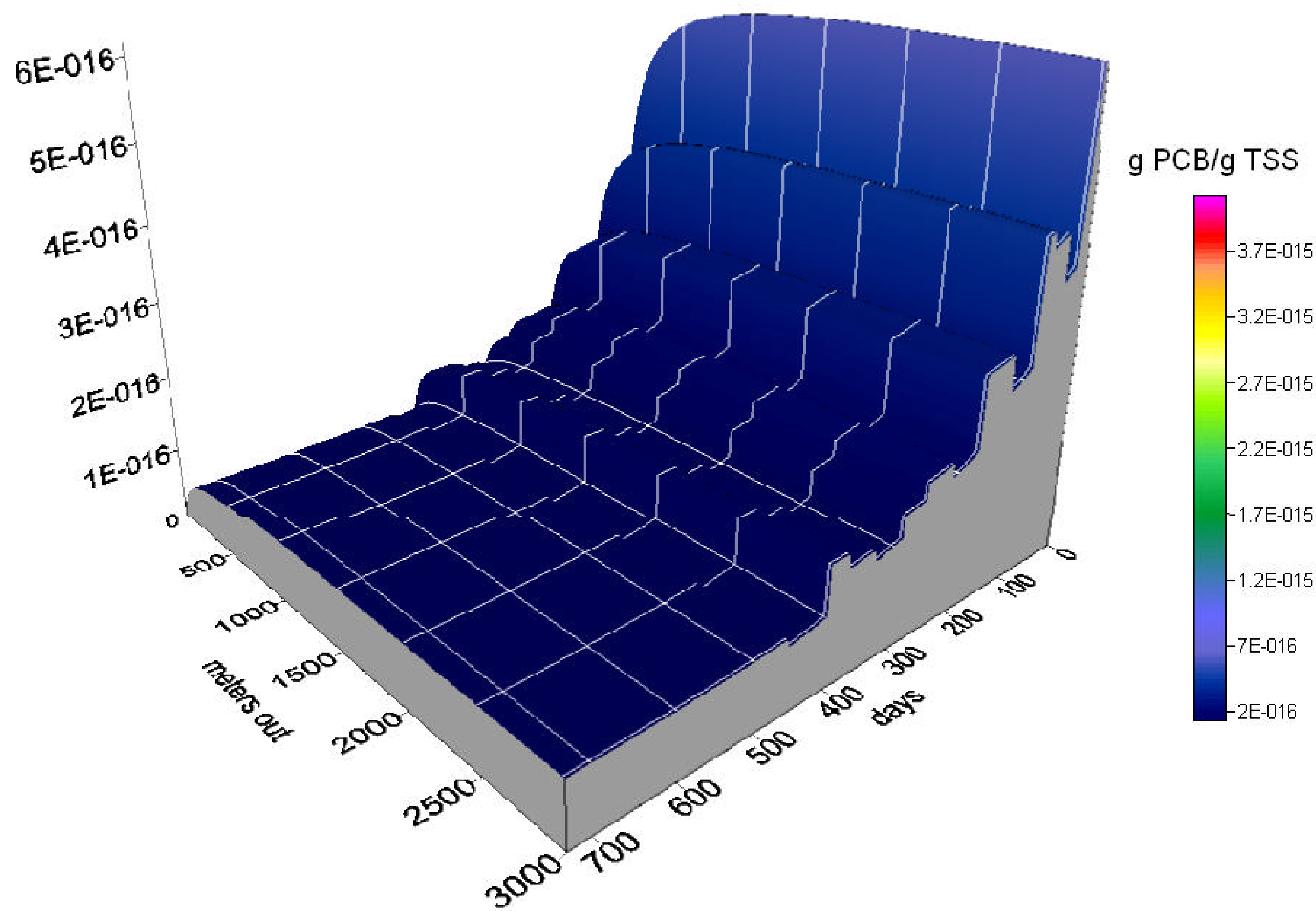


Figure B 66 - Pentachlorobiphenyl in TSS above Pycnocline

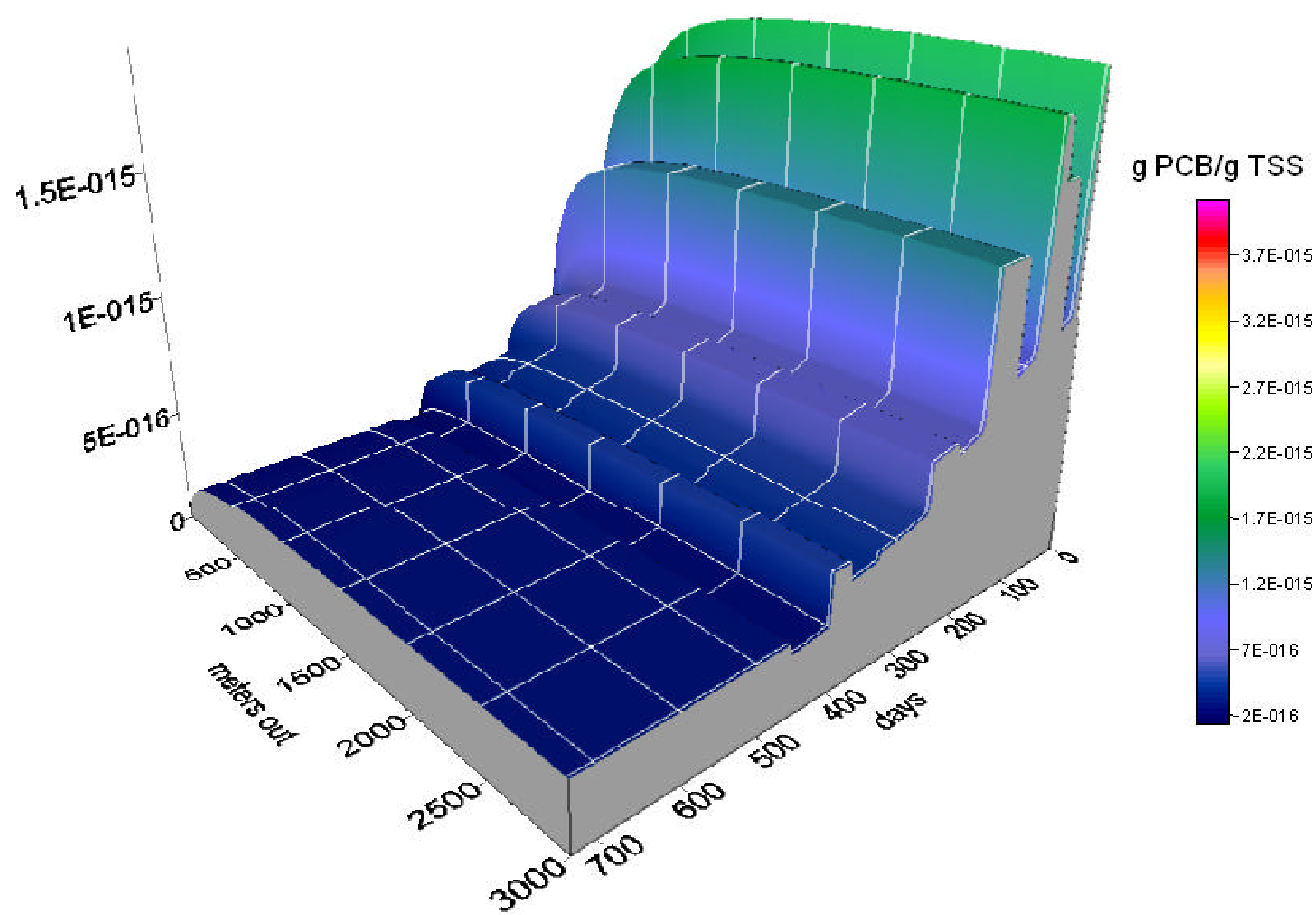


Figure B 67 - Hexachlorobiphenyl in TSS above Pycnocline

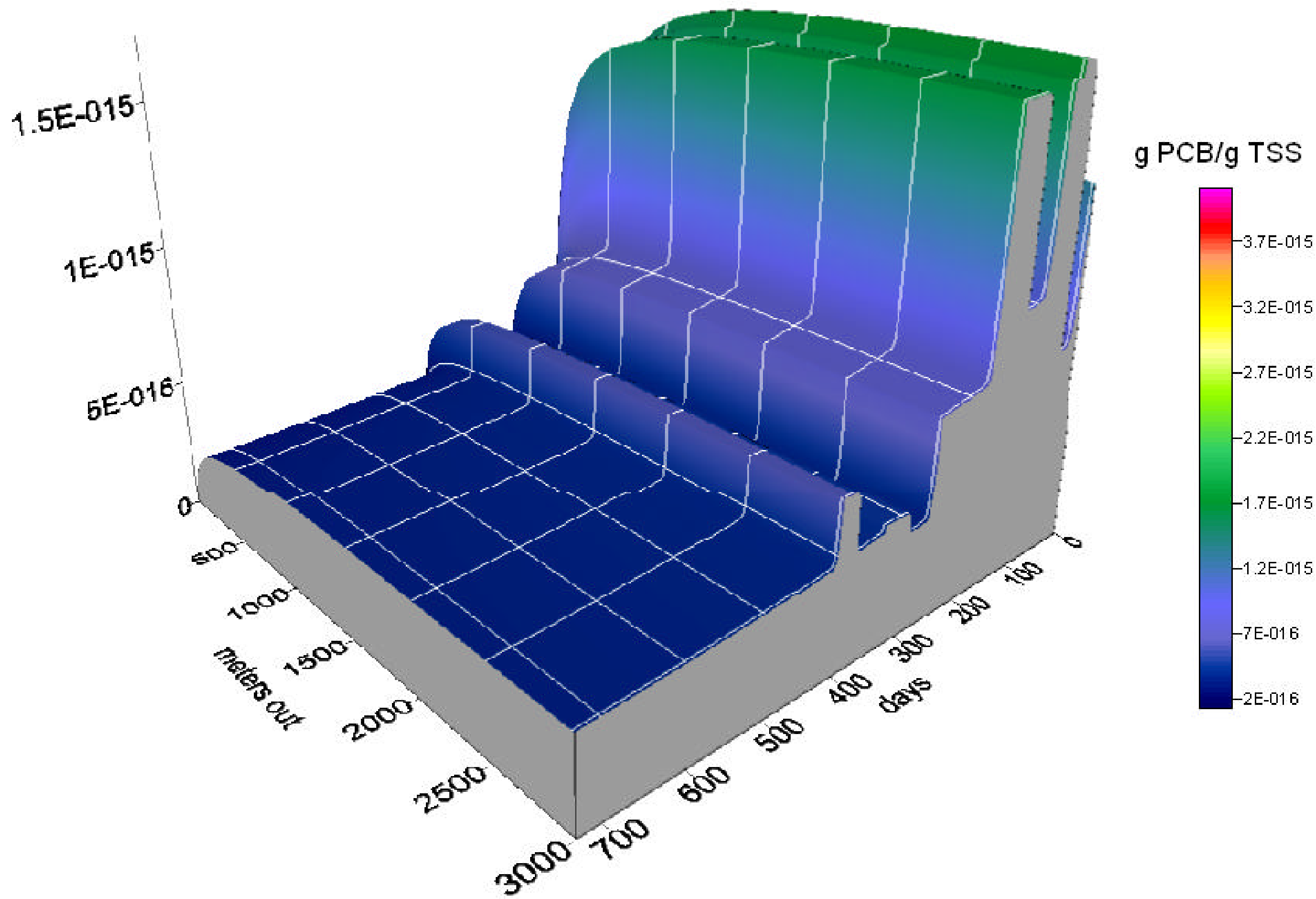


Figure B 68 - Heptachlorobiphenyl in TSS above Pycnocline

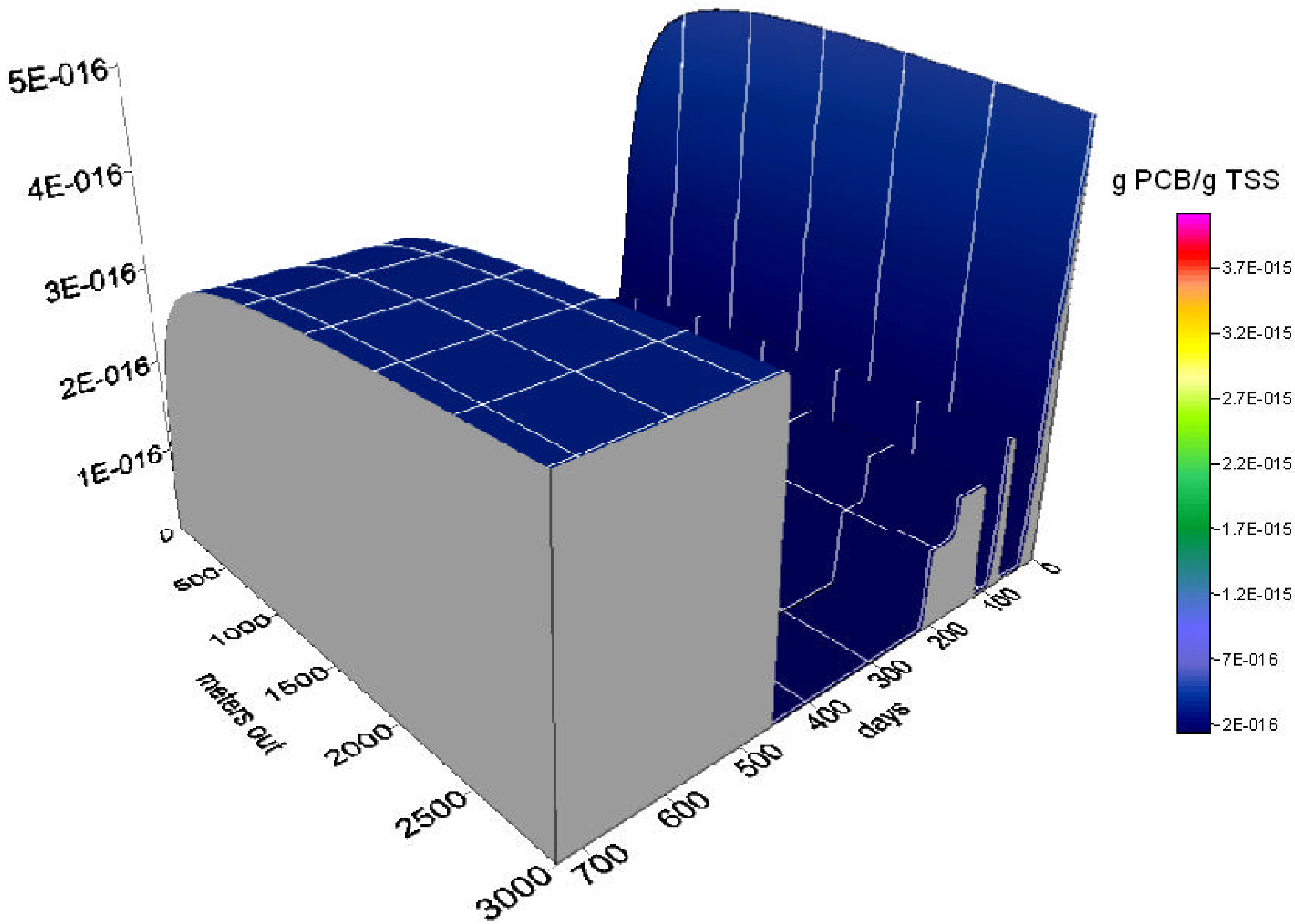


Figure B 69 - Nonachlorobiphenyl in TSS above Pycnocline

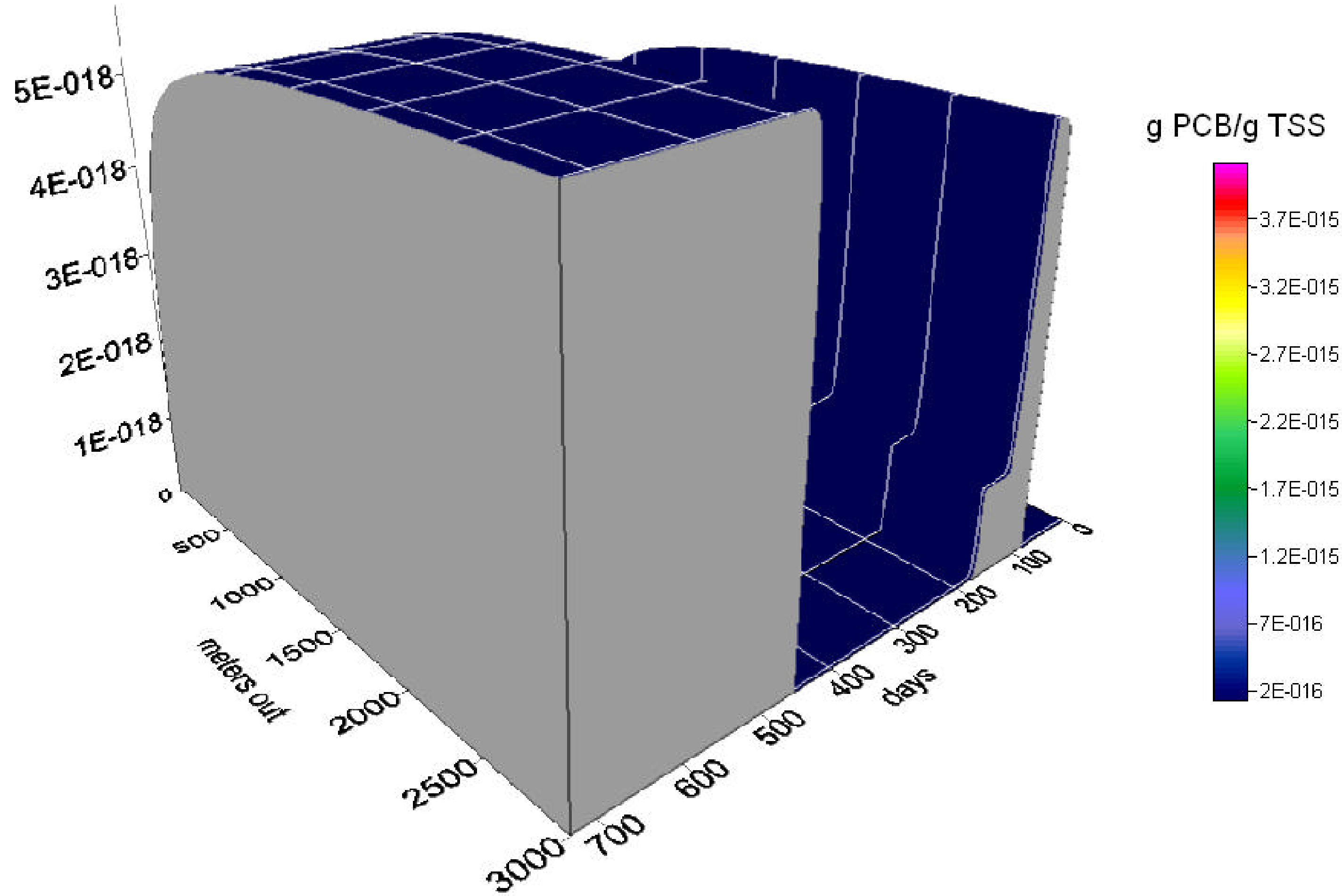


Figure B 70 - Decachlorobiphenyl in TSS above Pycnocline

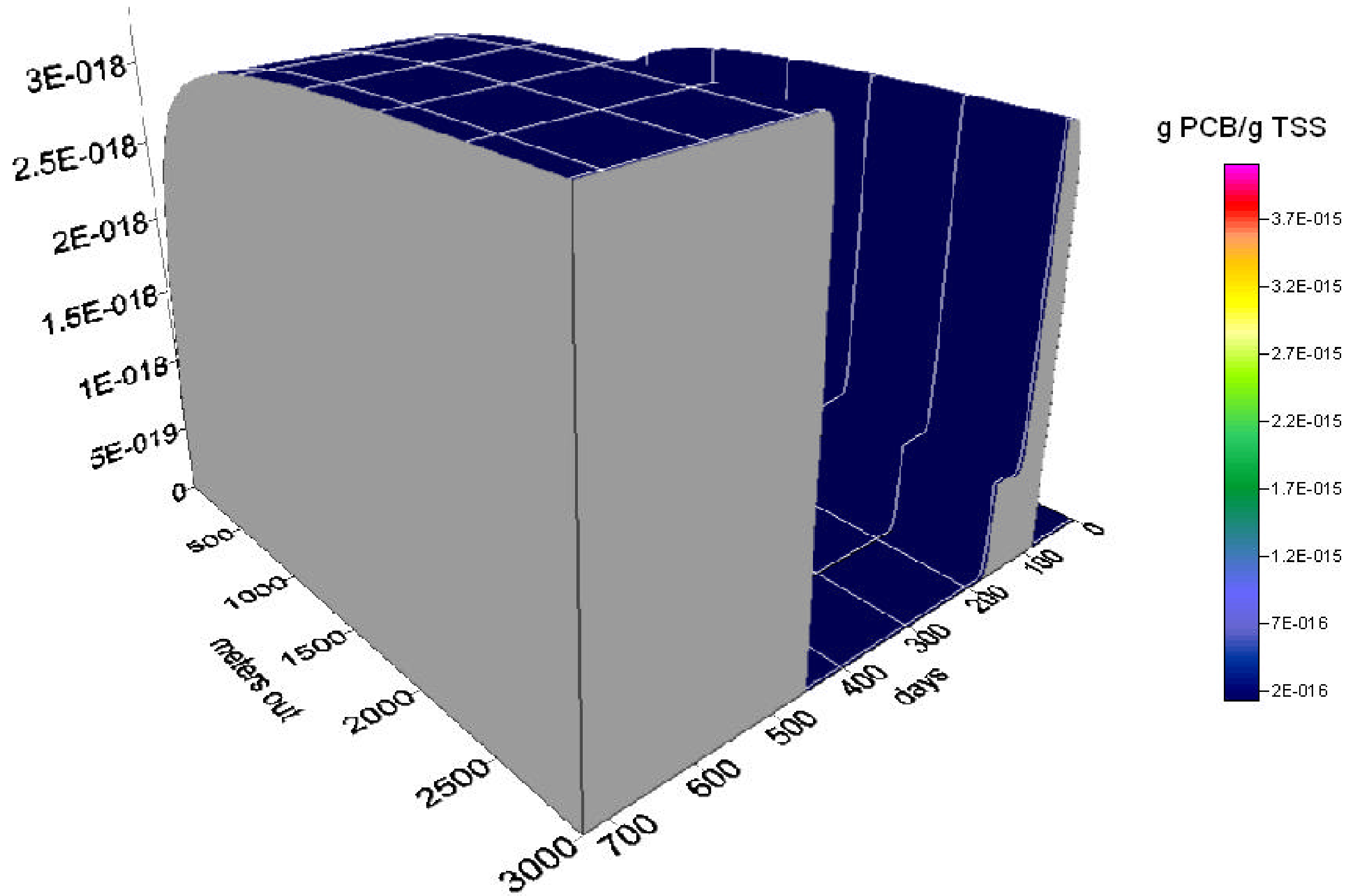


Figure C 1 – Monochlorobiphenyl Concentrations at Distances of Highest Concentrations

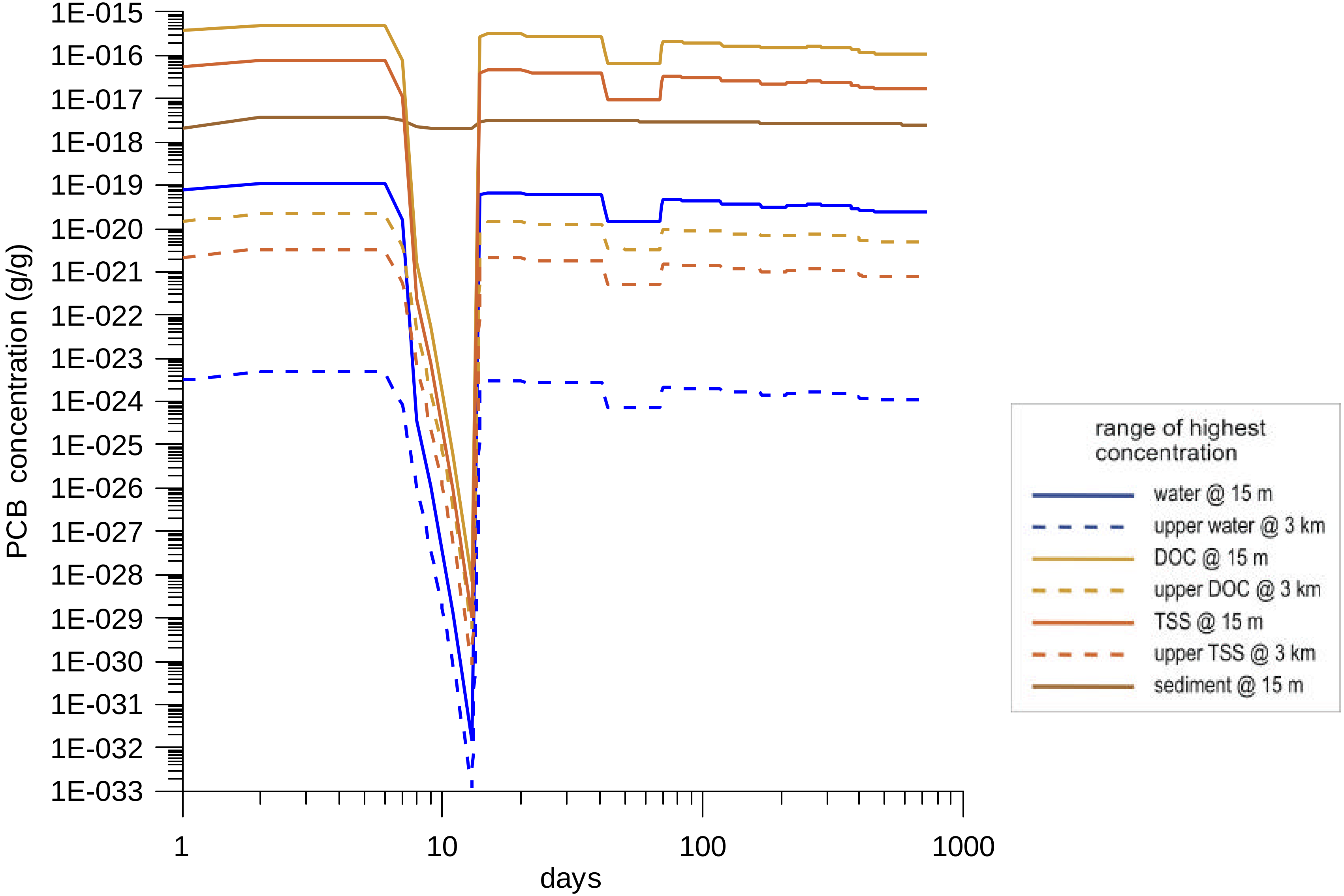


Figure C 2 – Monochlorobiphenyl Concentrations and Total Released Mass inside the Ship

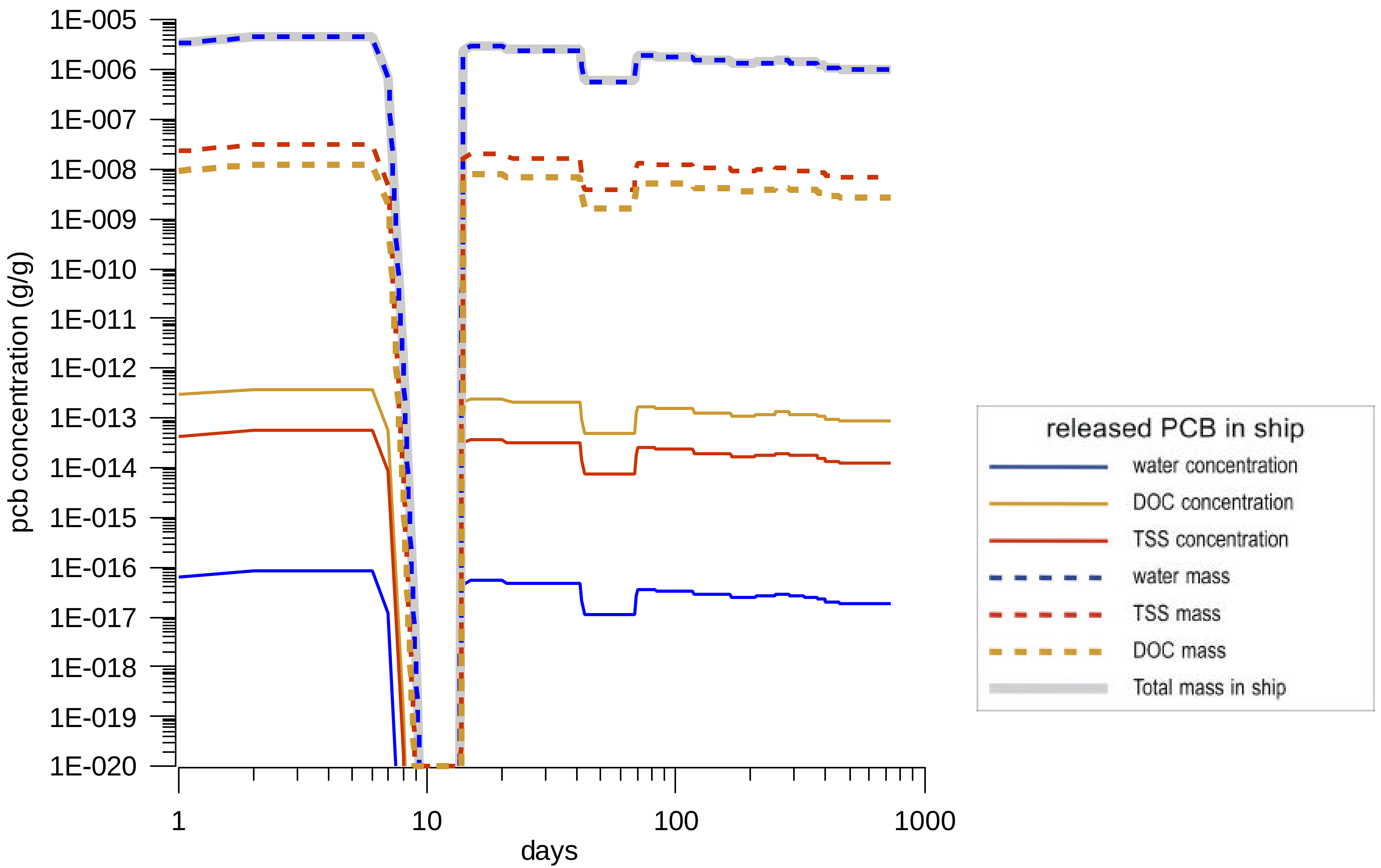


Figure C 3 – Monochlorobiphenyl Mass Budget

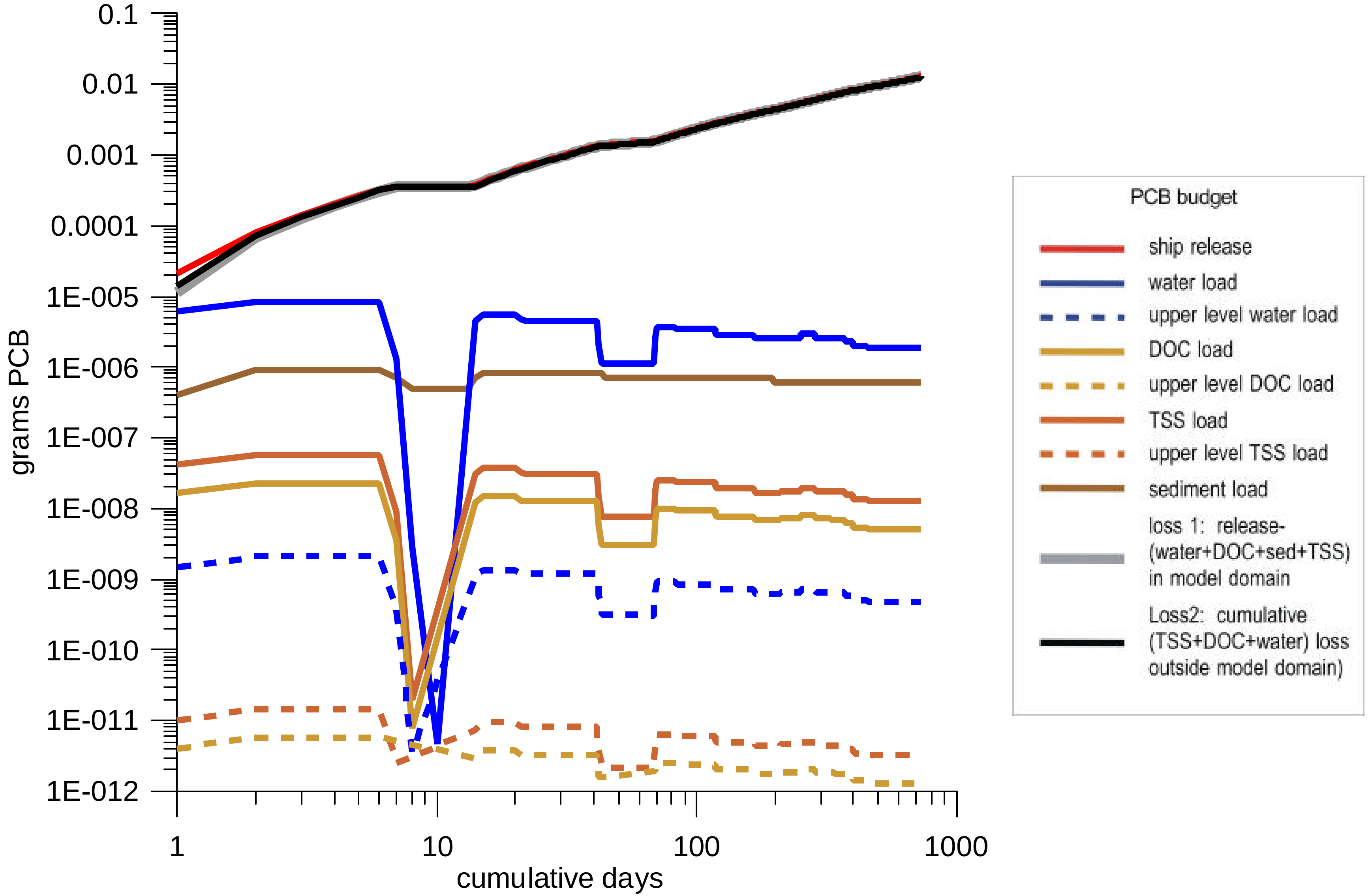


Figure C 4 –Dichlorobiphenyl Concentrations at Distances of Highest Concentrations

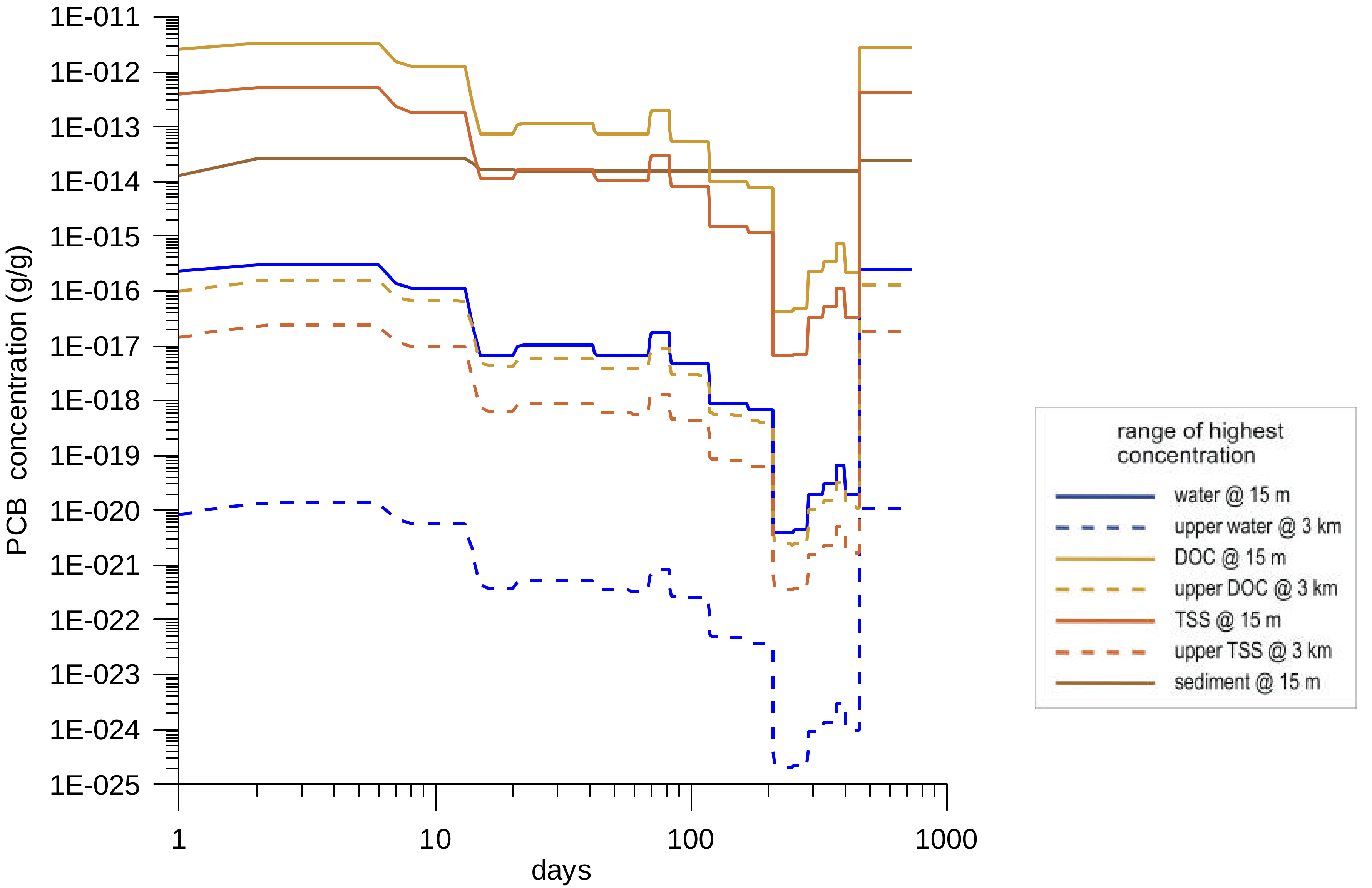


Figure C 5 – Dichlorobiphenyl Concentrations and Total Released Mass inside theShip

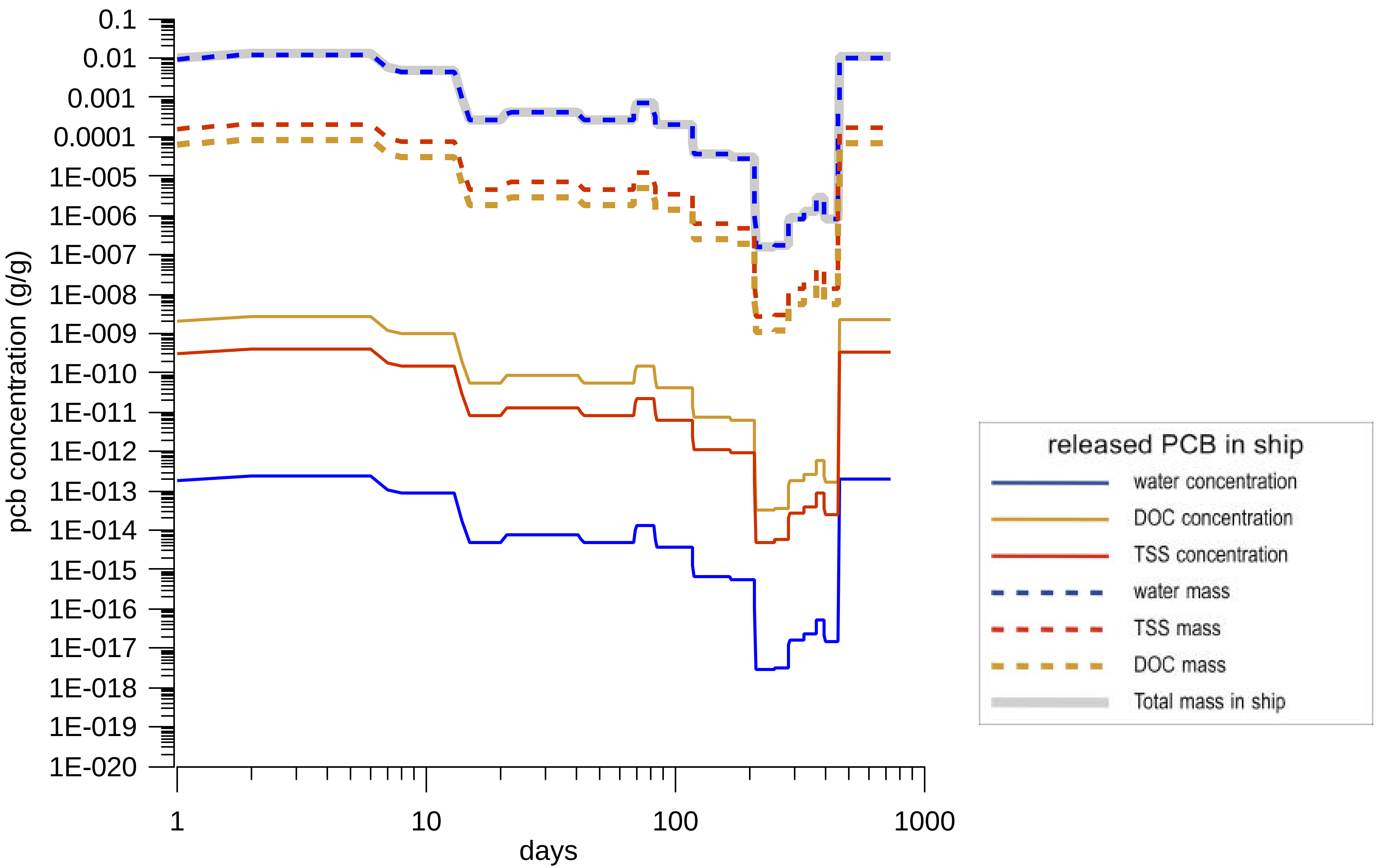


Figure C 6 – Dichlorobiphenyl Mass Budget

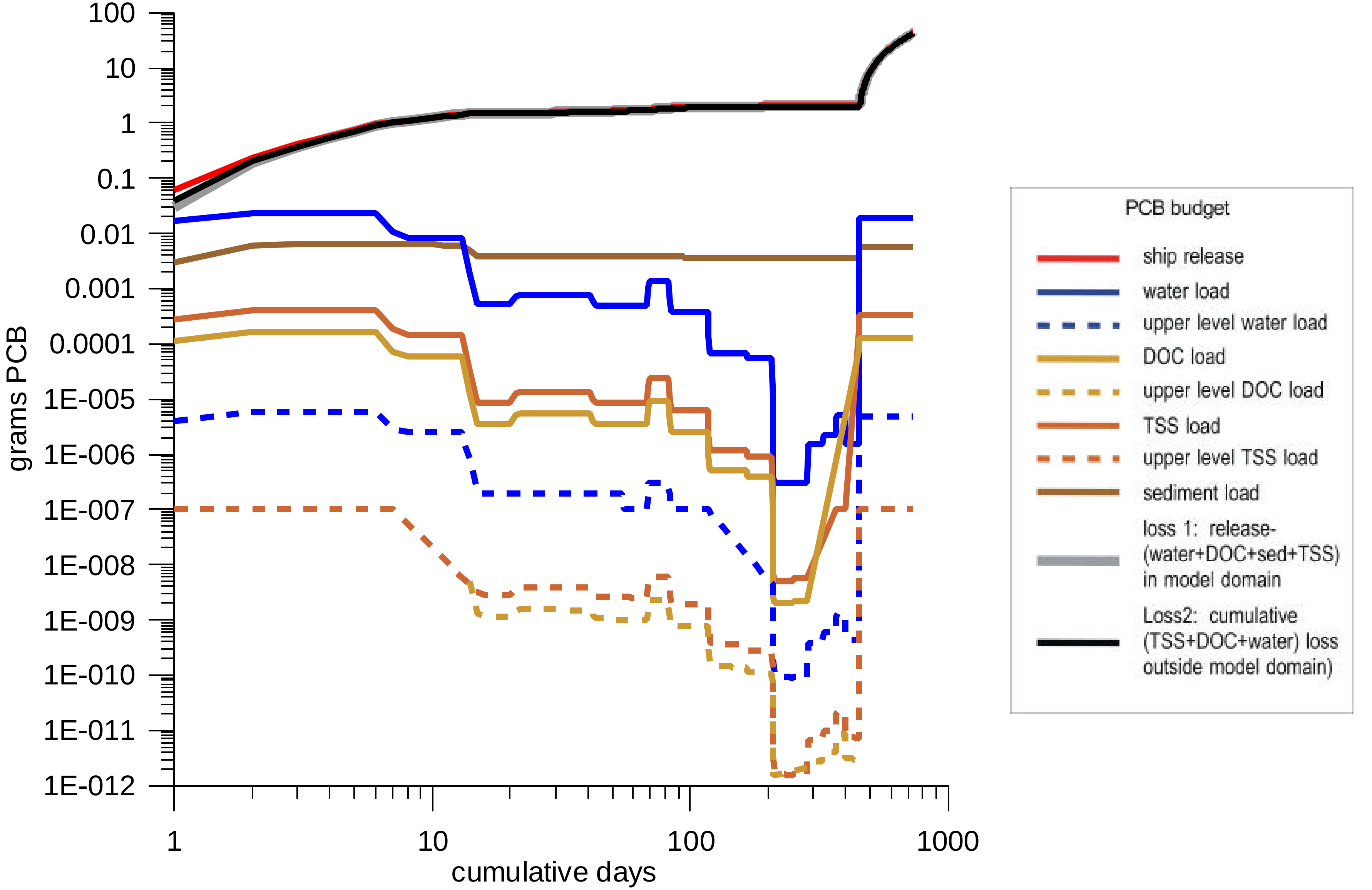


Figure C 7 – Trichlorobiphenyl Concentrations at Distances of Highest Concentrations

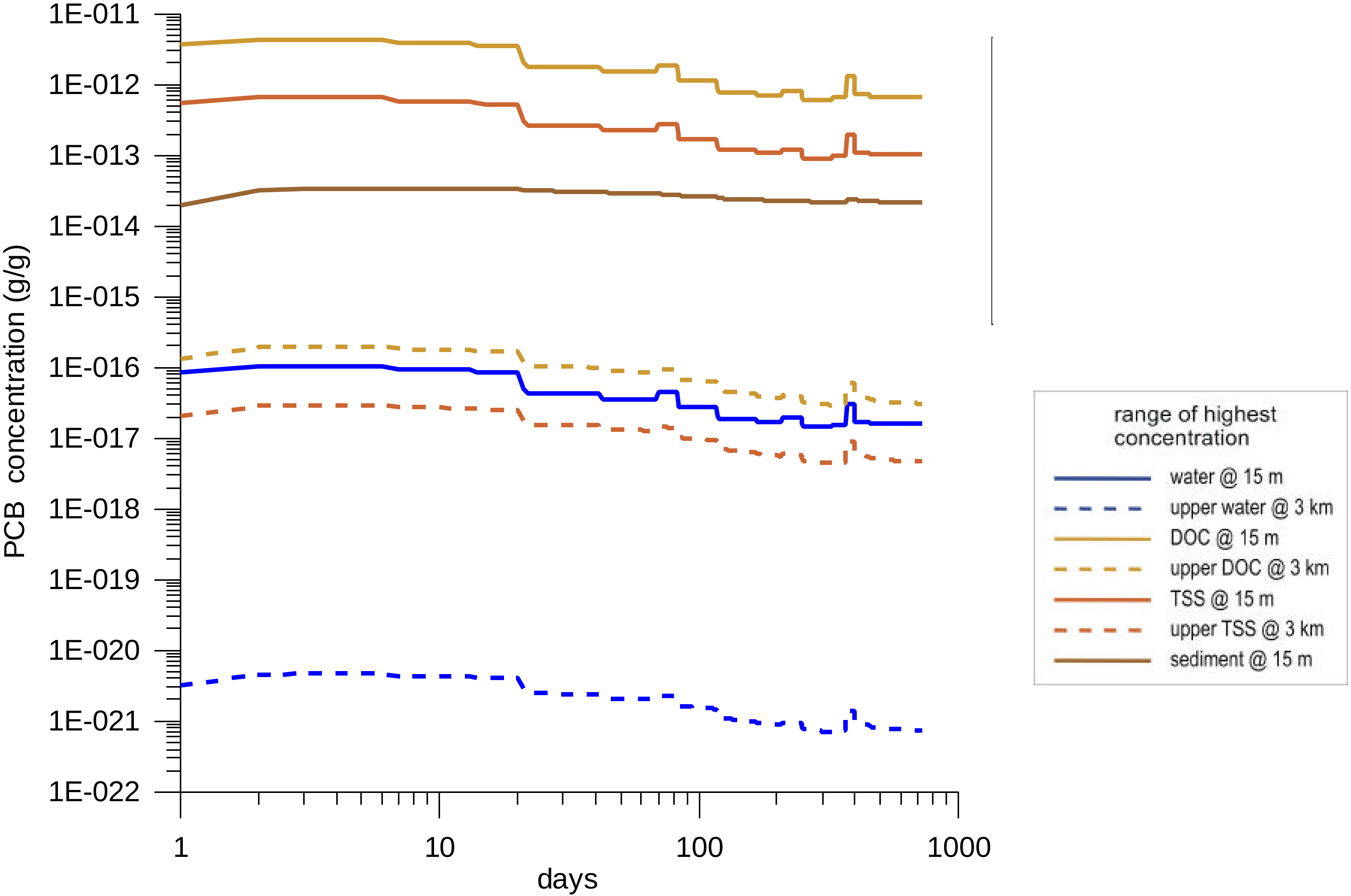


Figure C 8 – Trichlorobiphenyl Concentrations and Total Released Mass inside the Ship

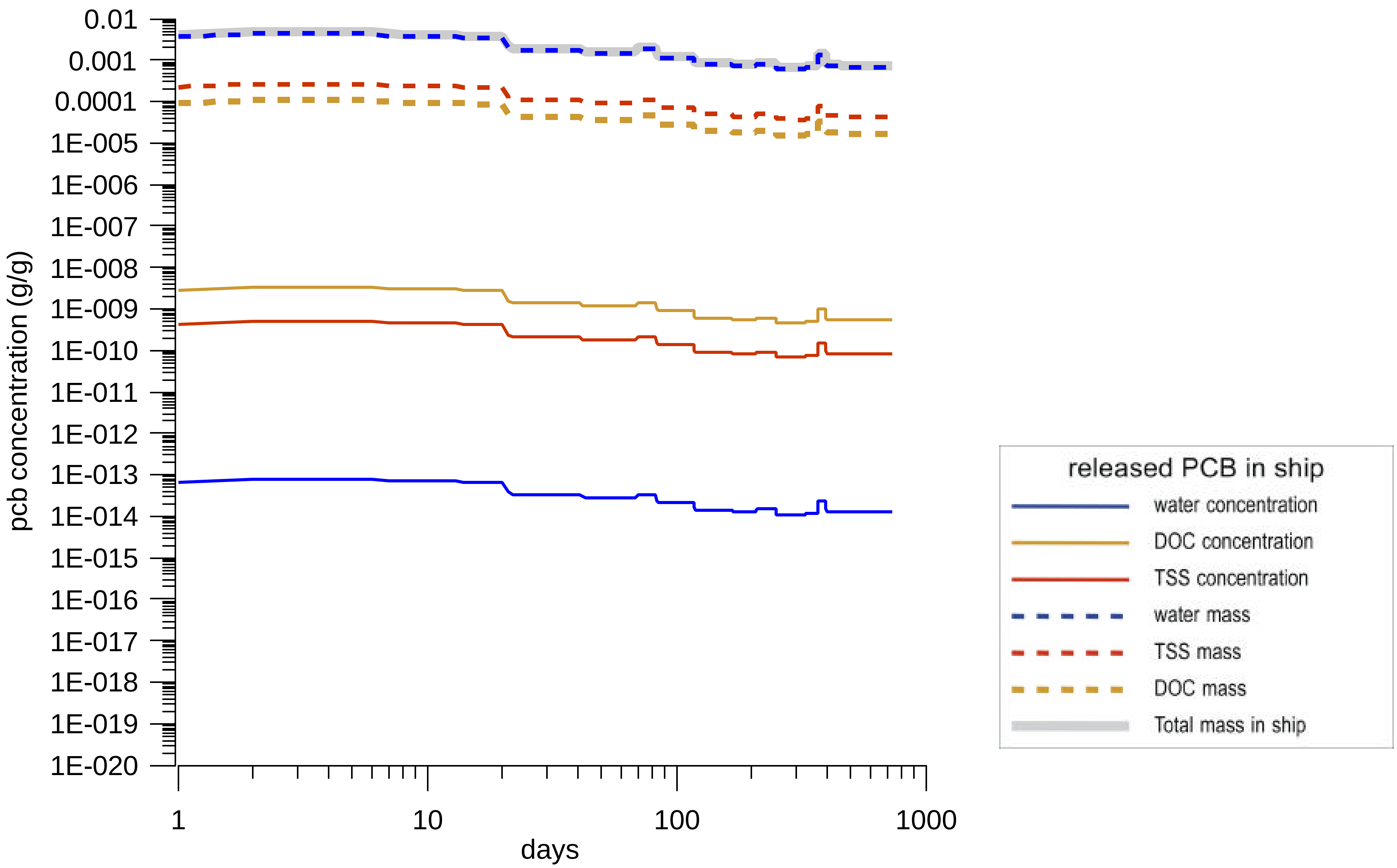


Figure C 9 – Trichlorobiphenyl Mass Budget

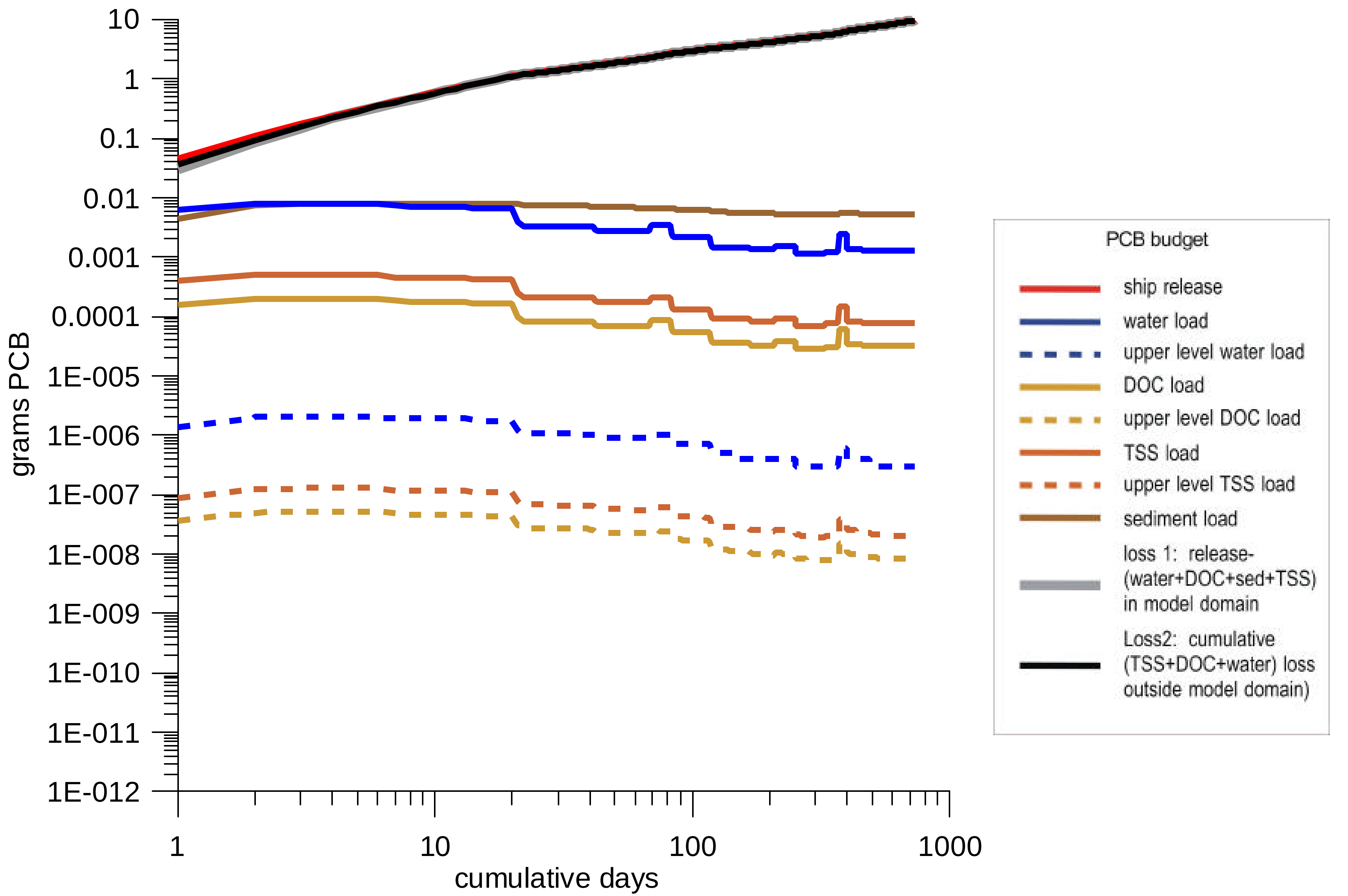


Figure C 10 – Tetrachlorobiphenyl Concentrations at Distances of Highest Concentrations

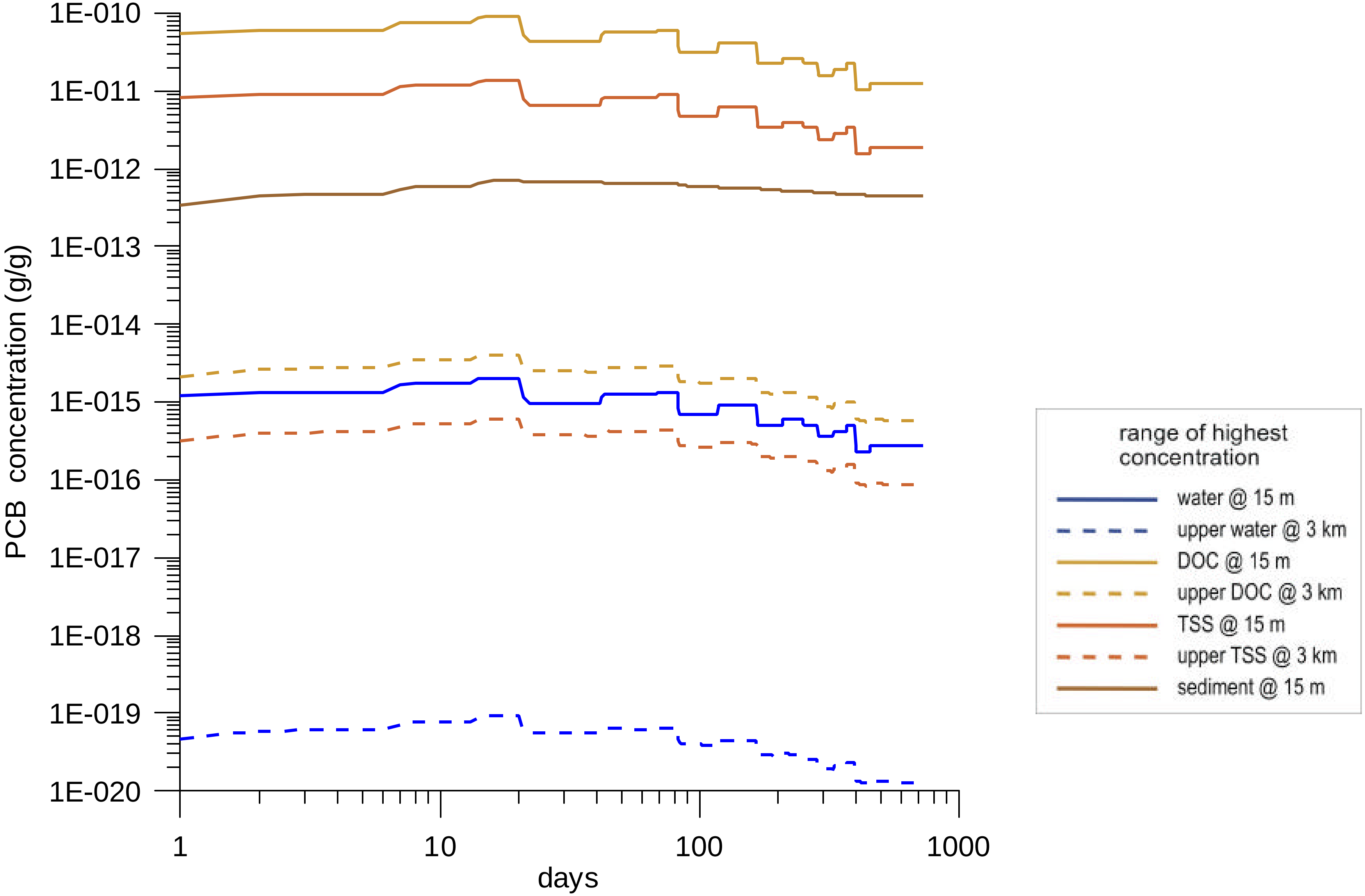


Figure C 11 – Tetrachlorobiphenyl Concentrations and Total Released Mass inside the Ship

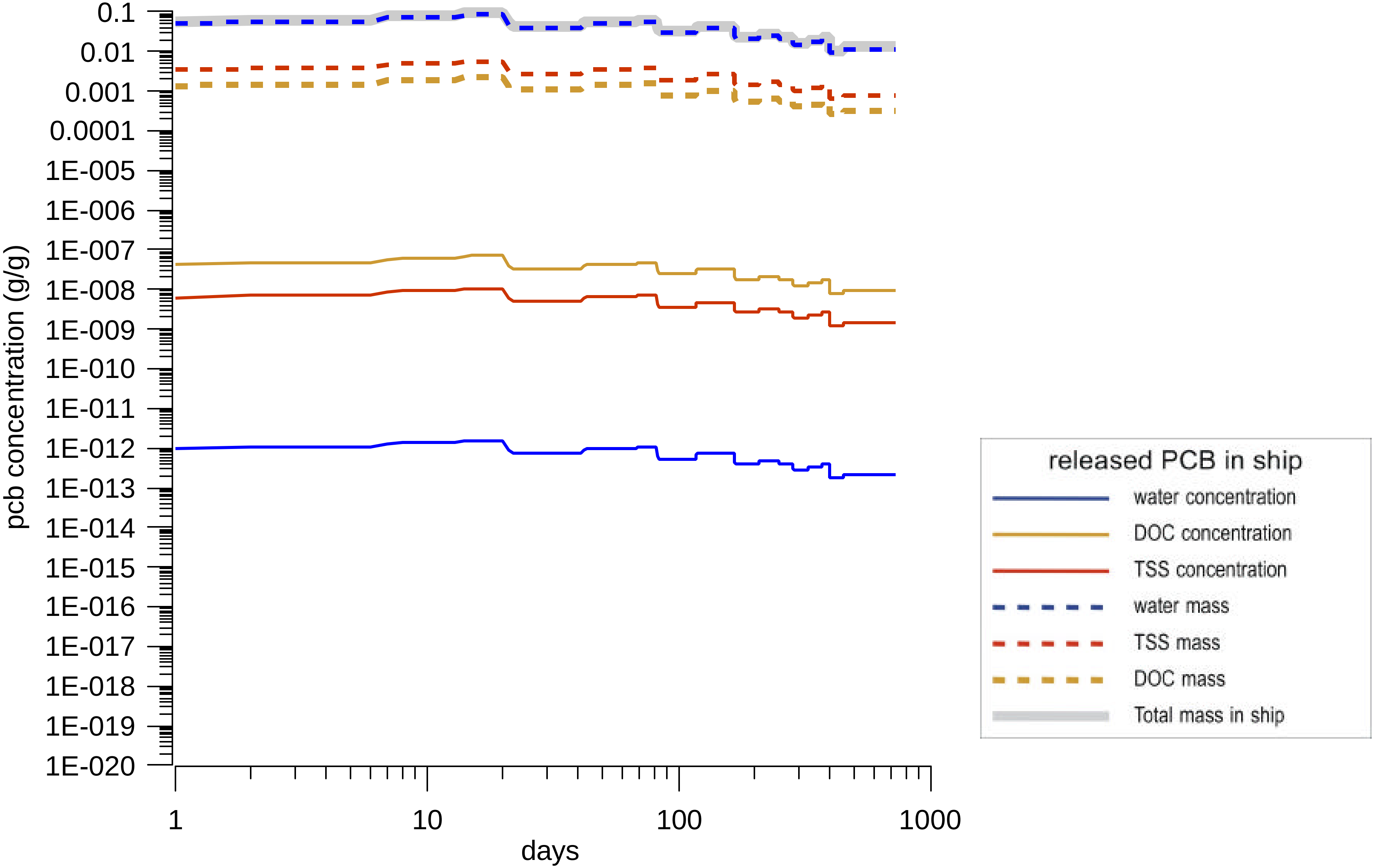


Figure C 12 – Tetrachlorobiphenyl Mass Budget

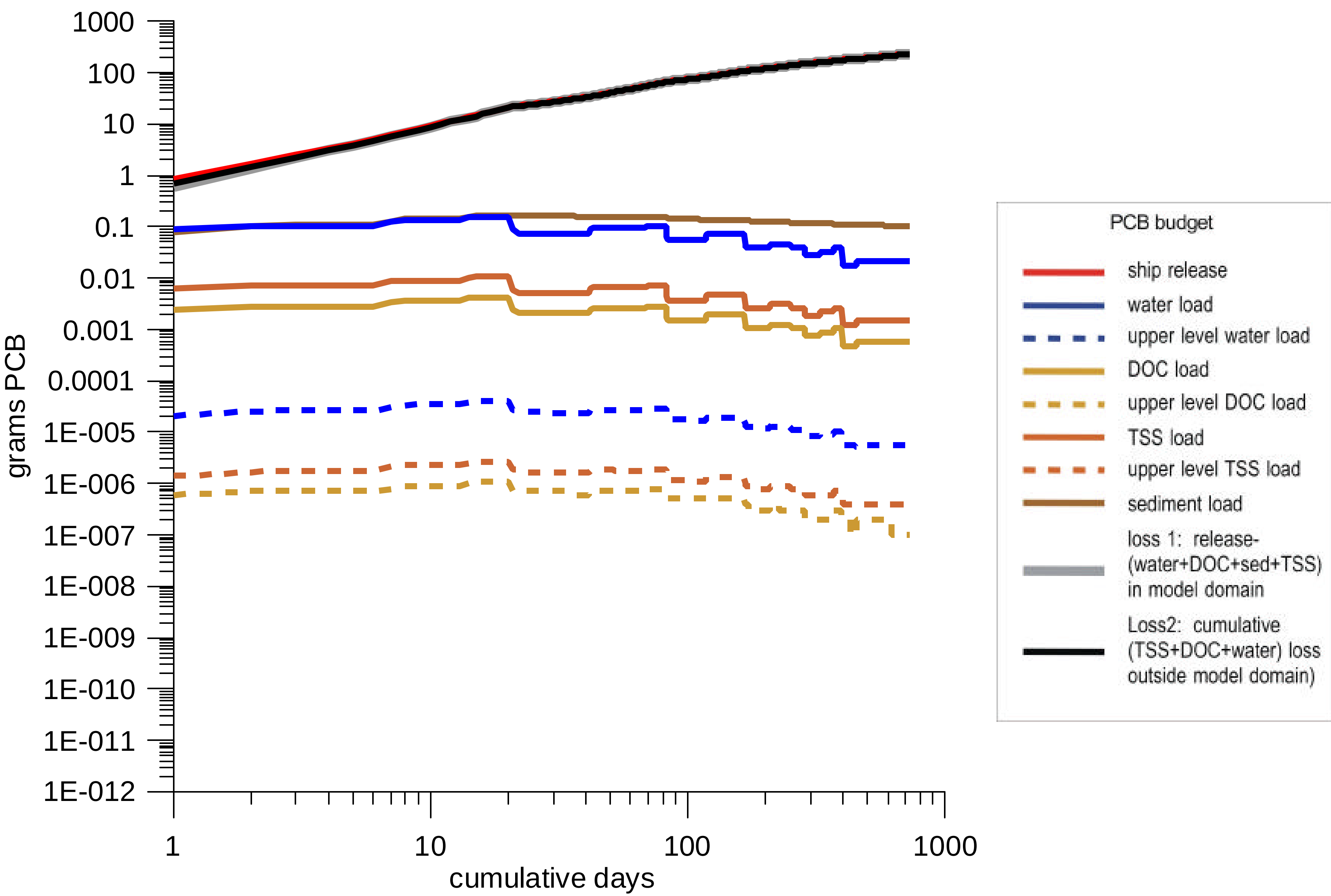


Figure C 13 –Pentachlorobiphenyl Concentrations at Distances of Highest Concentrations

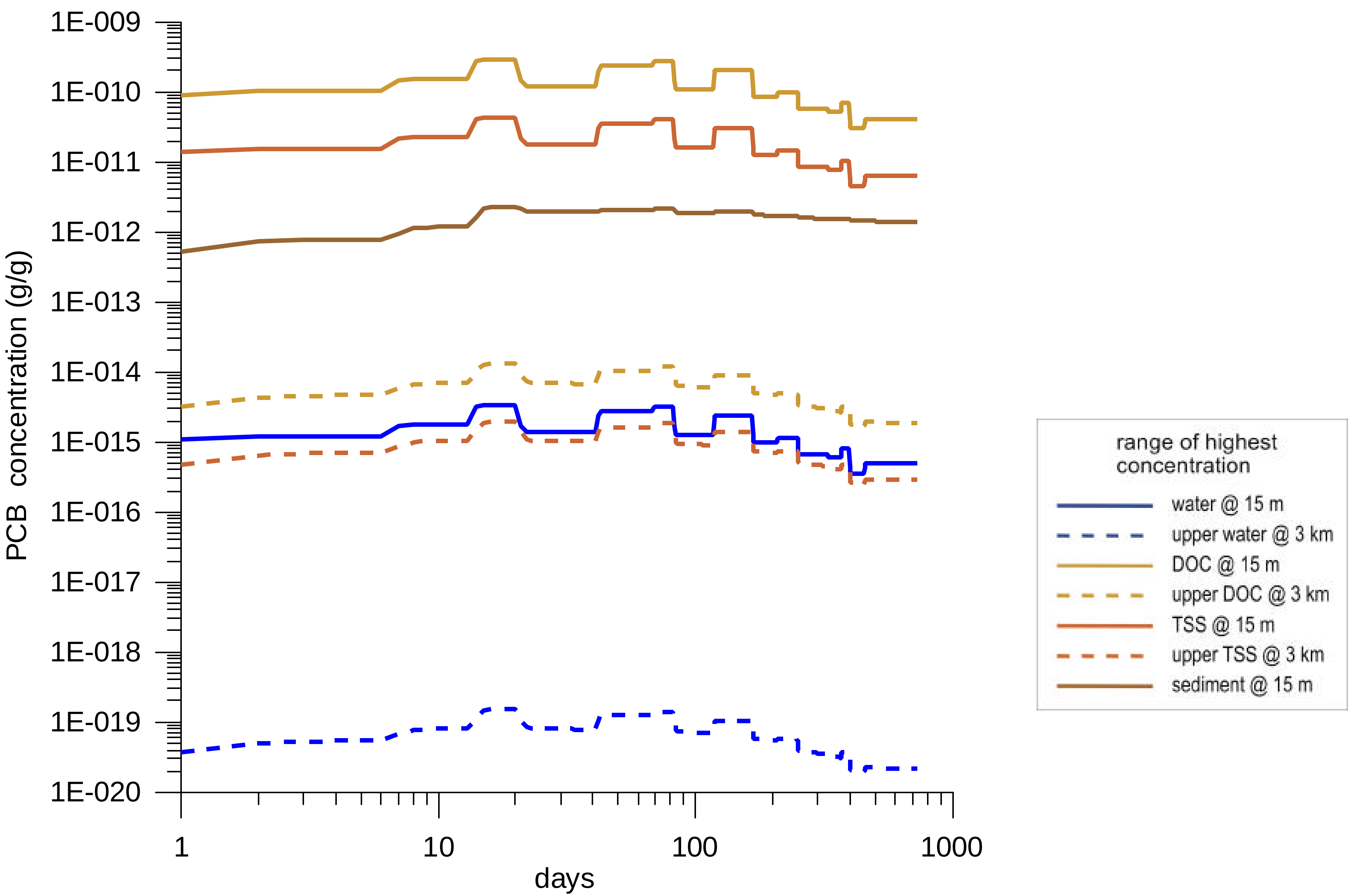


Figure C 14 – Pentachlorobiphenyl Concentrations and Total Released Mass inside the Ship

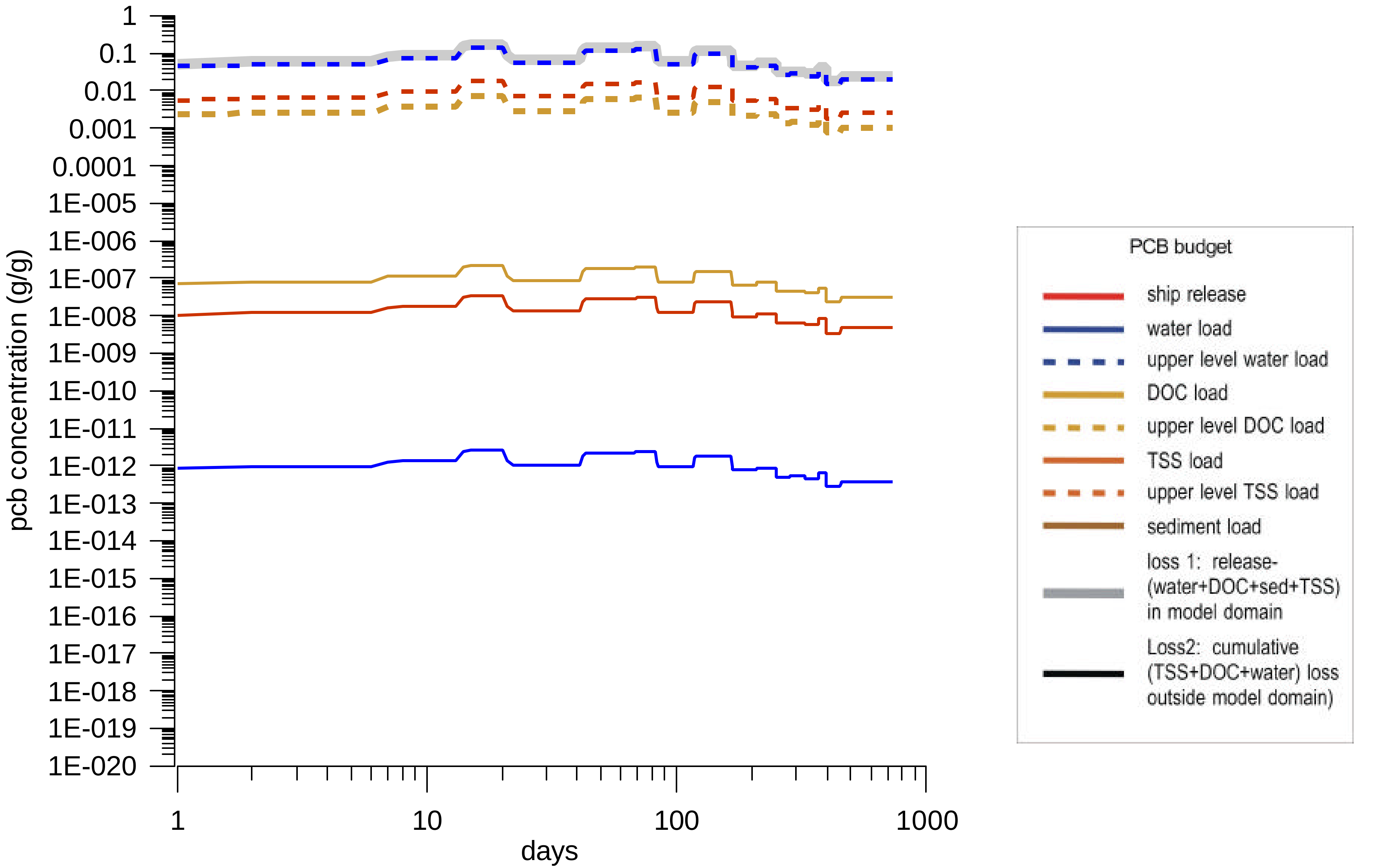


Figure C 15 – Pentachlorobiphenyl Mass Budget

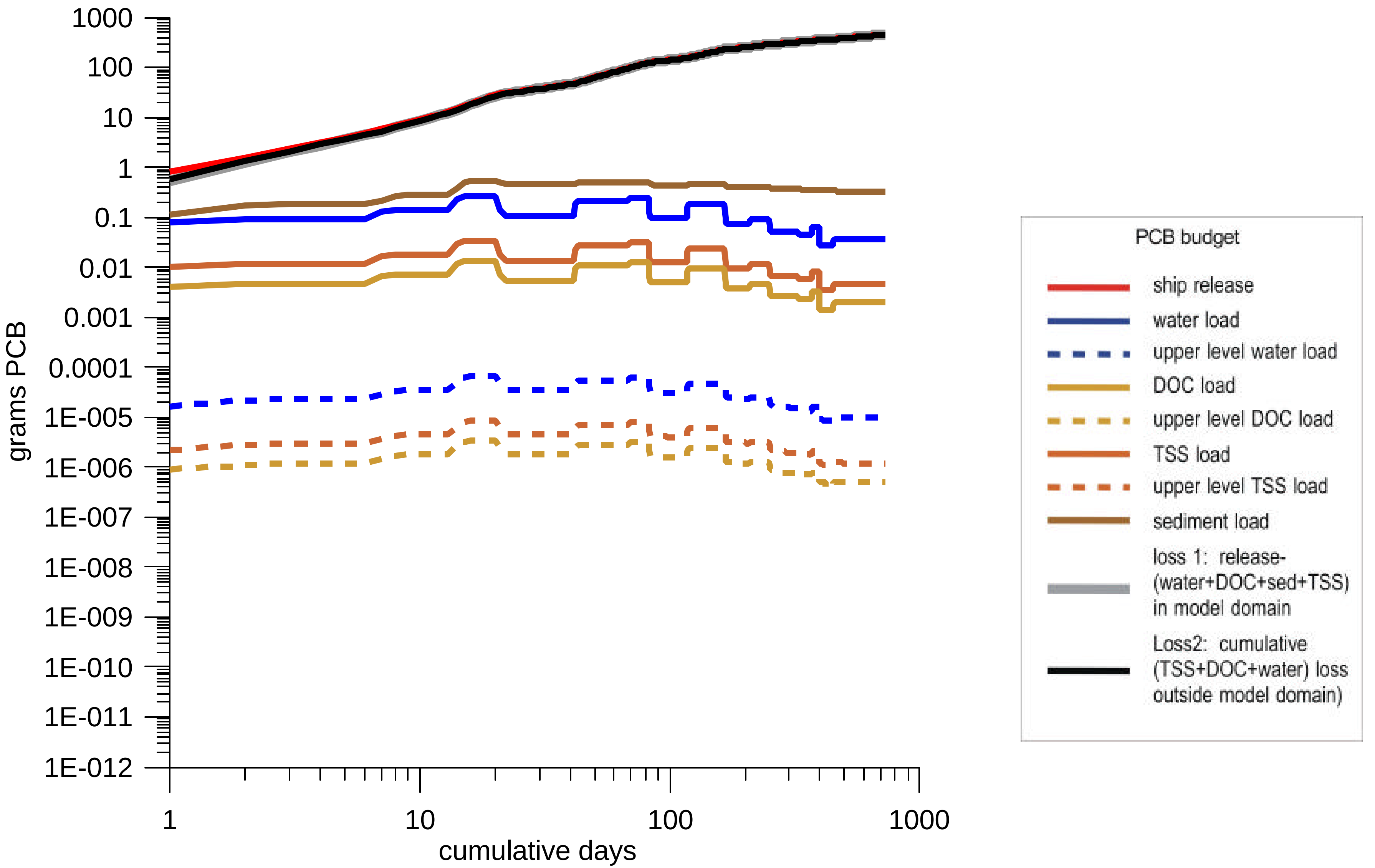


Figure C 16 – Hexachlorobiphenyl Concentrations at Distances of Highest Concentrations

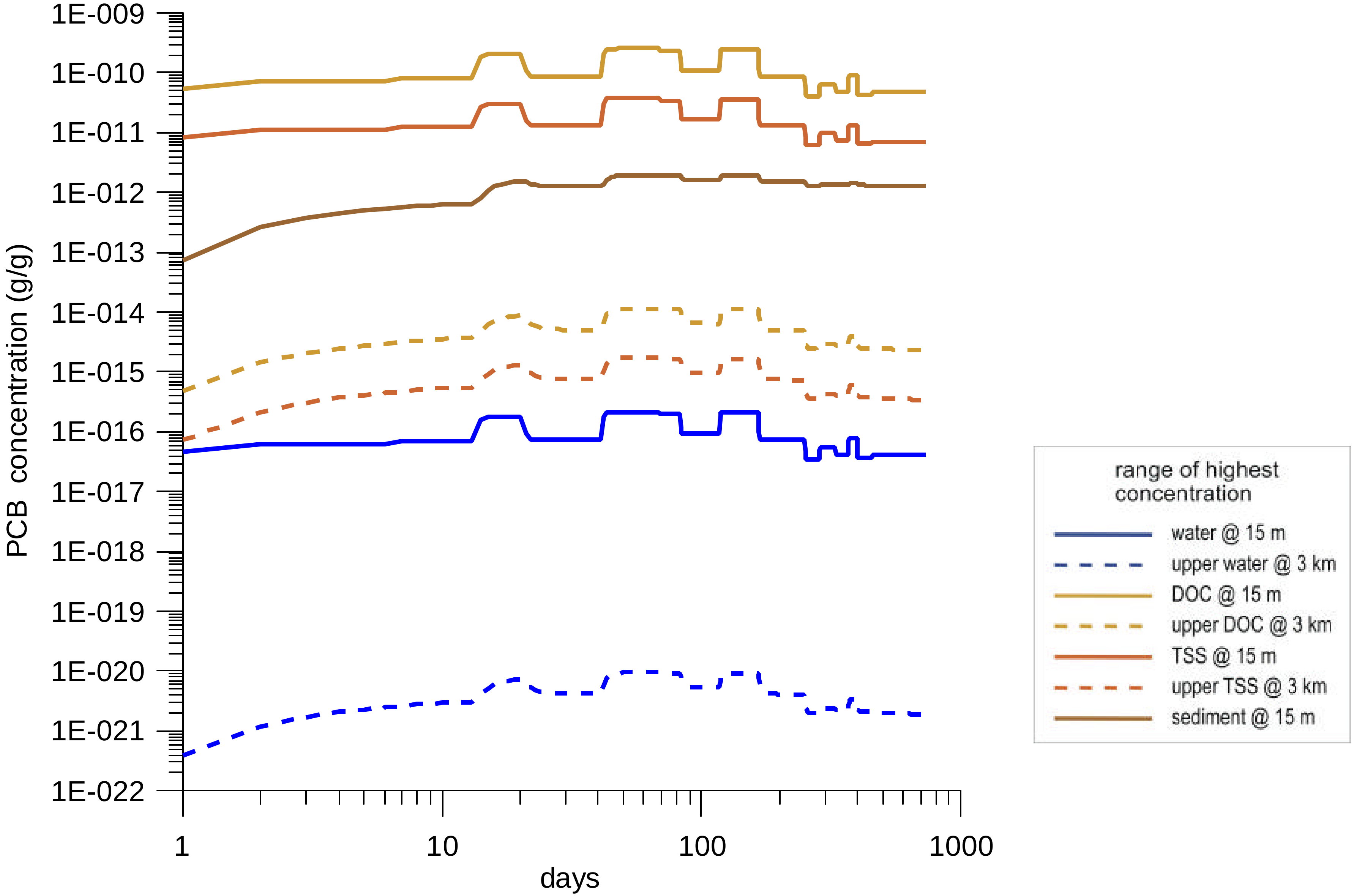


Figure C 17 – Hexachlorobiphenyl Concentrations and Total Released Mass inside the Ship

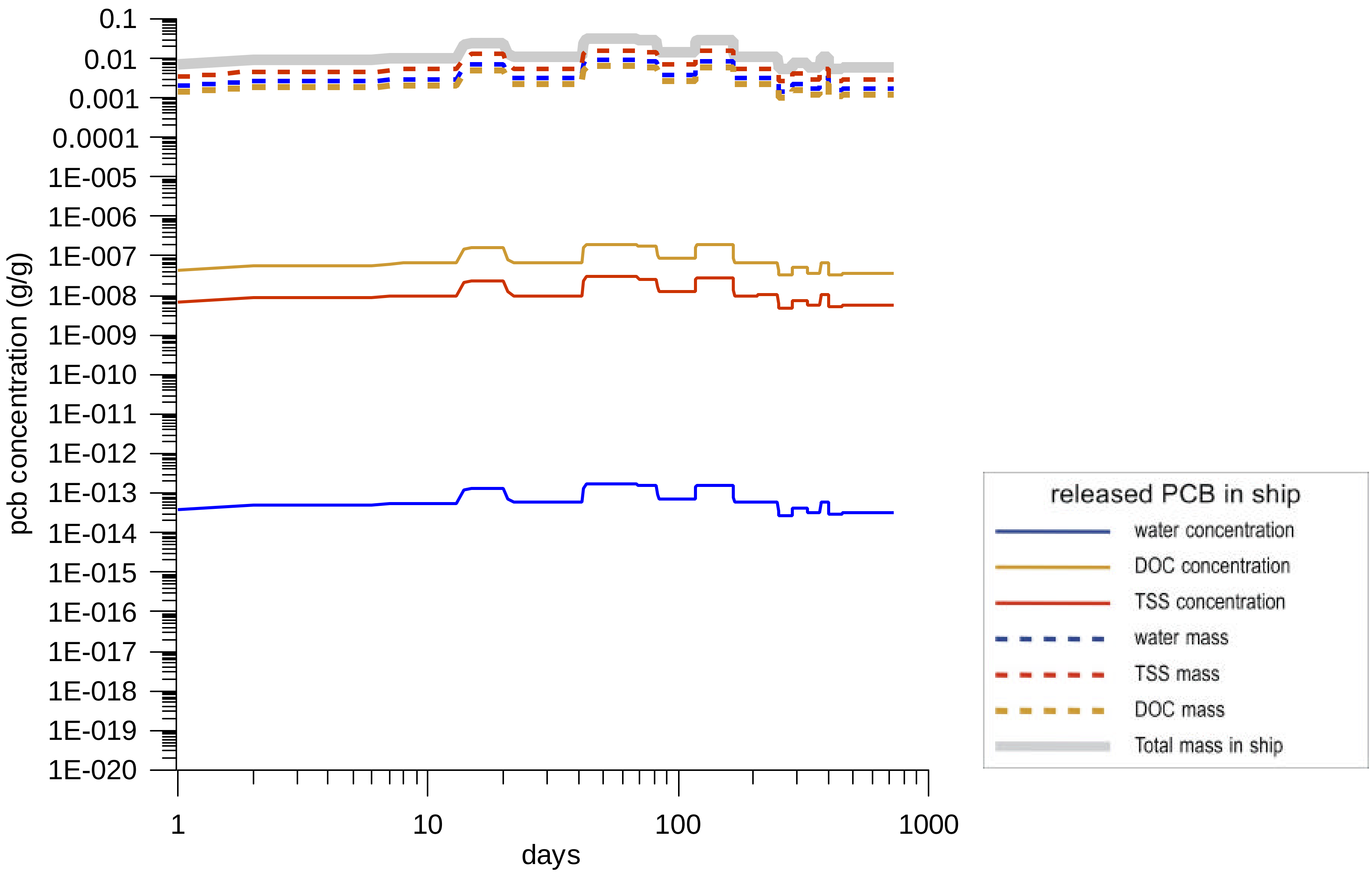


Figure C 18 – Hexachlorobiphenyl Mass Budget

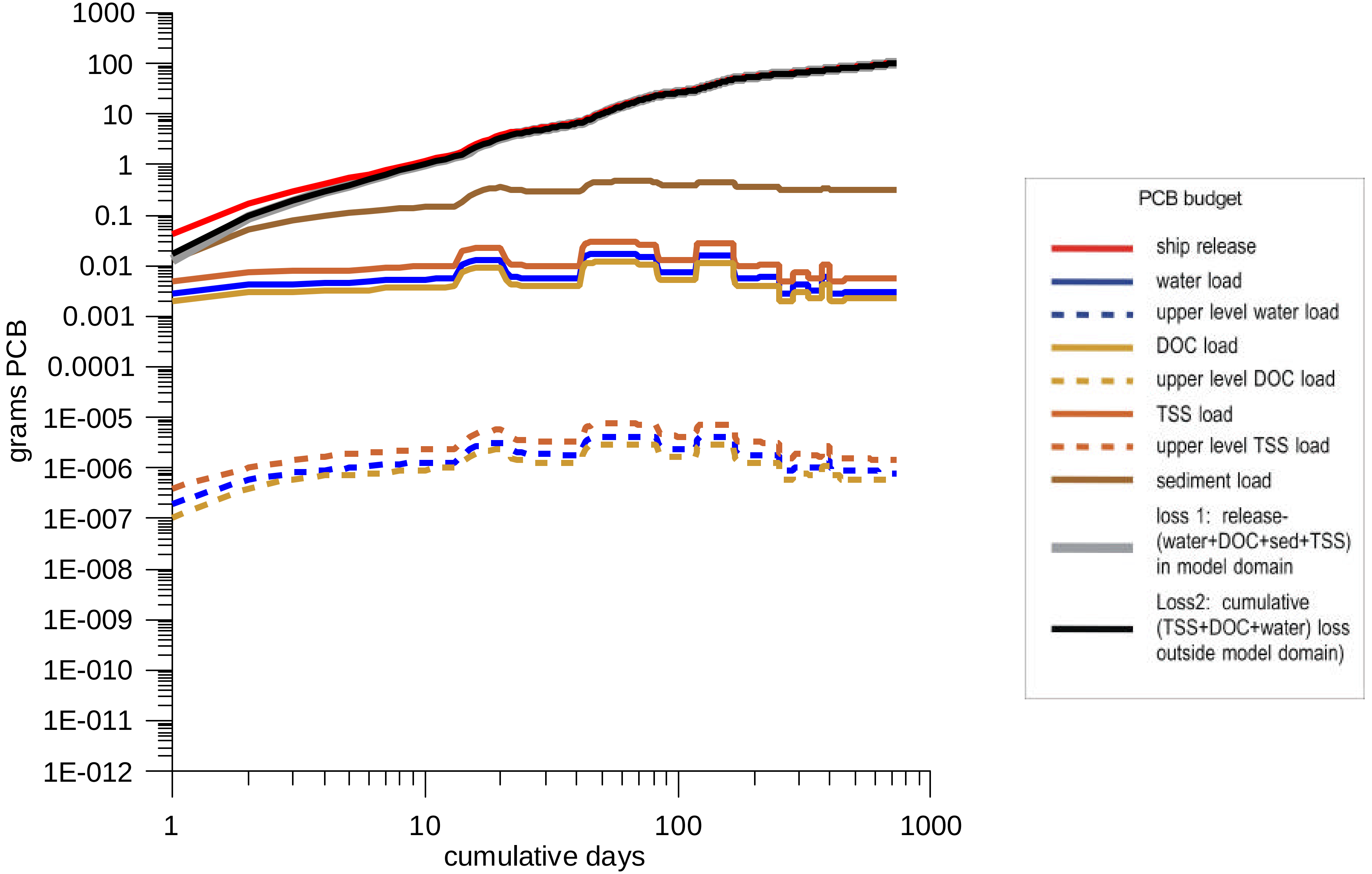


Figure C 19 – Heptachlorobiphenyl Concentrations at Distances of Highest Concentrations

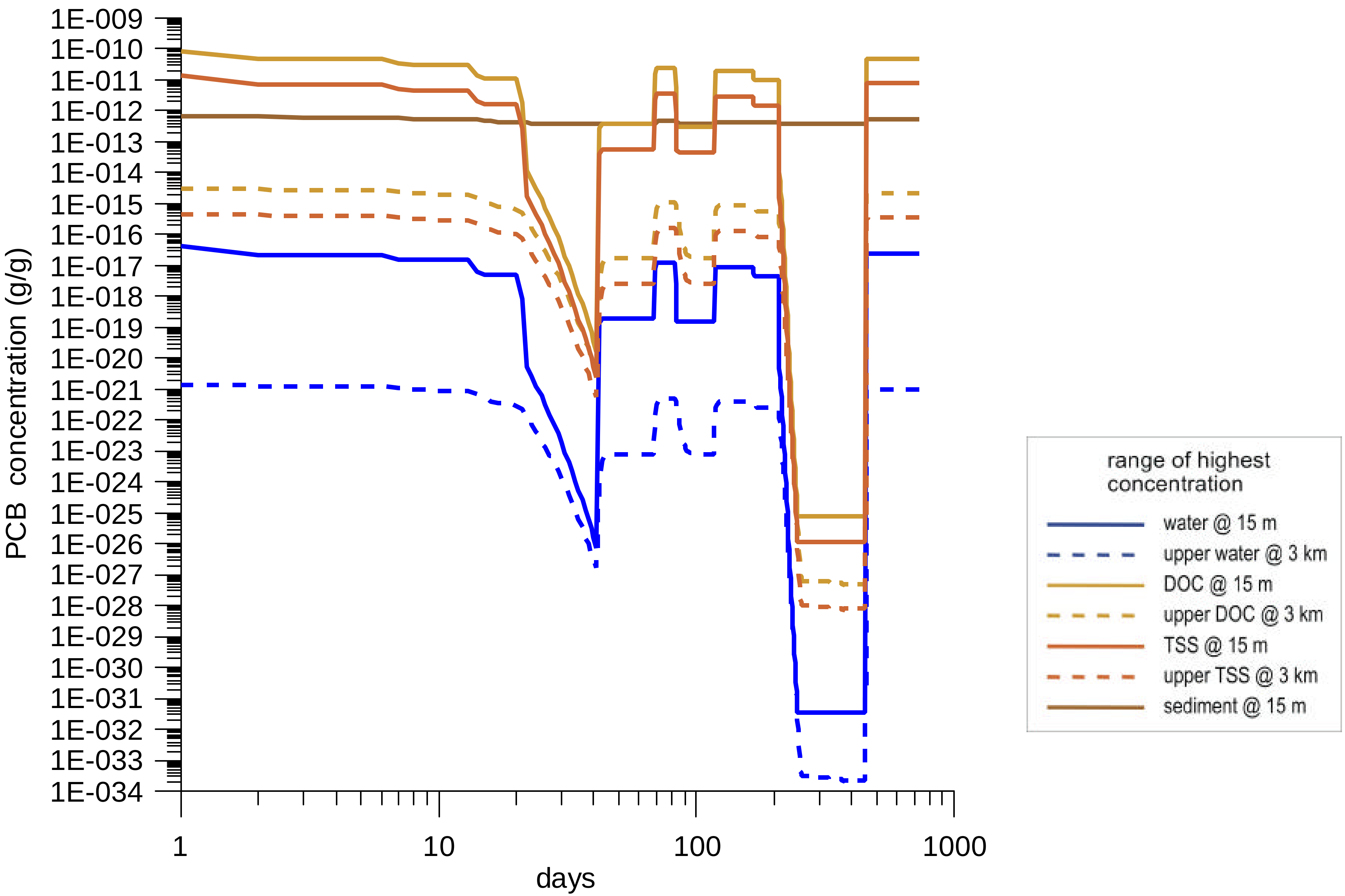


Figure C 20 – Heptachlorobiphenyl Concentrations and Total Released Mass inside the Ship

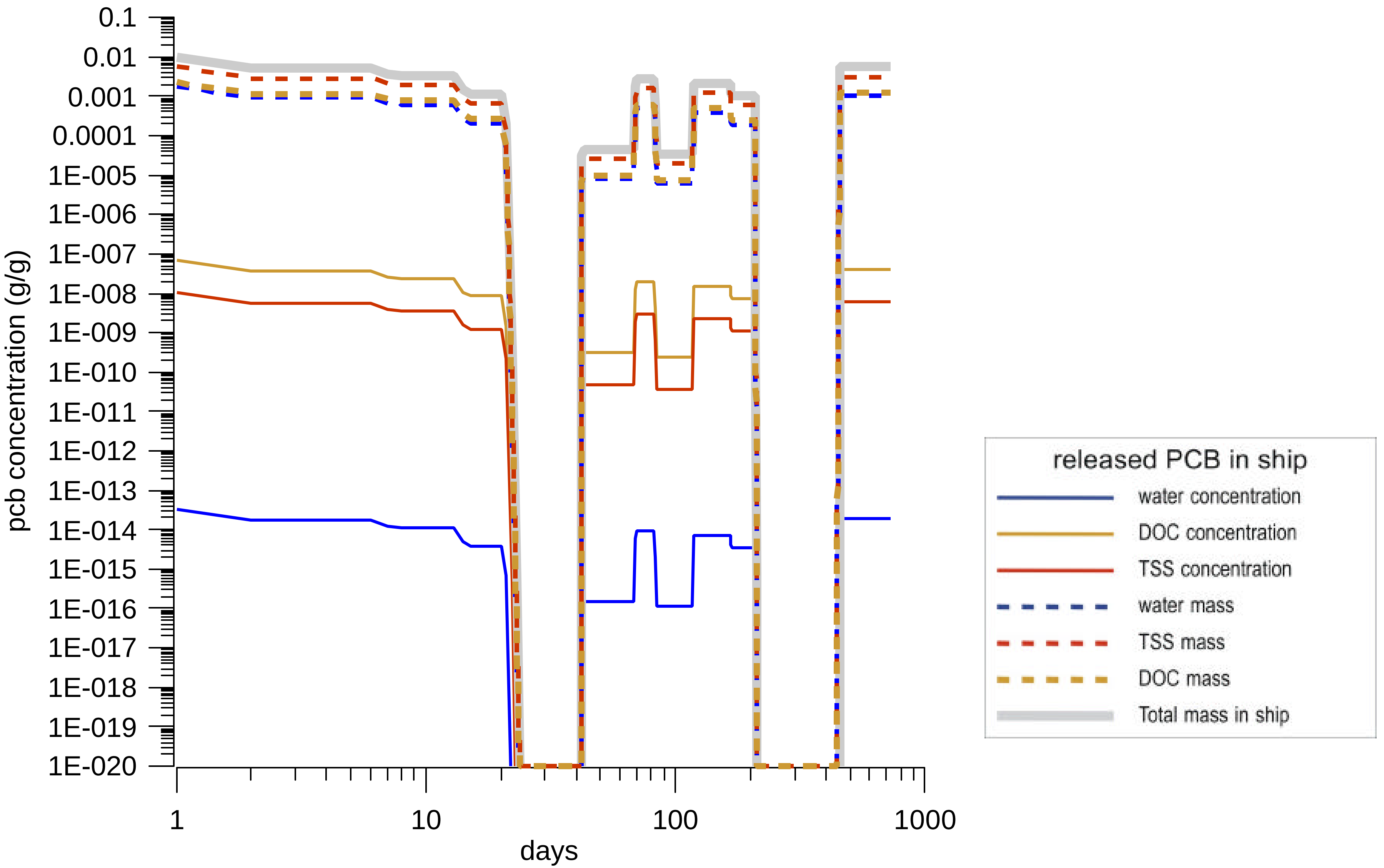


Figure C 21 – Heptachlorobiphenyl Mass Budget

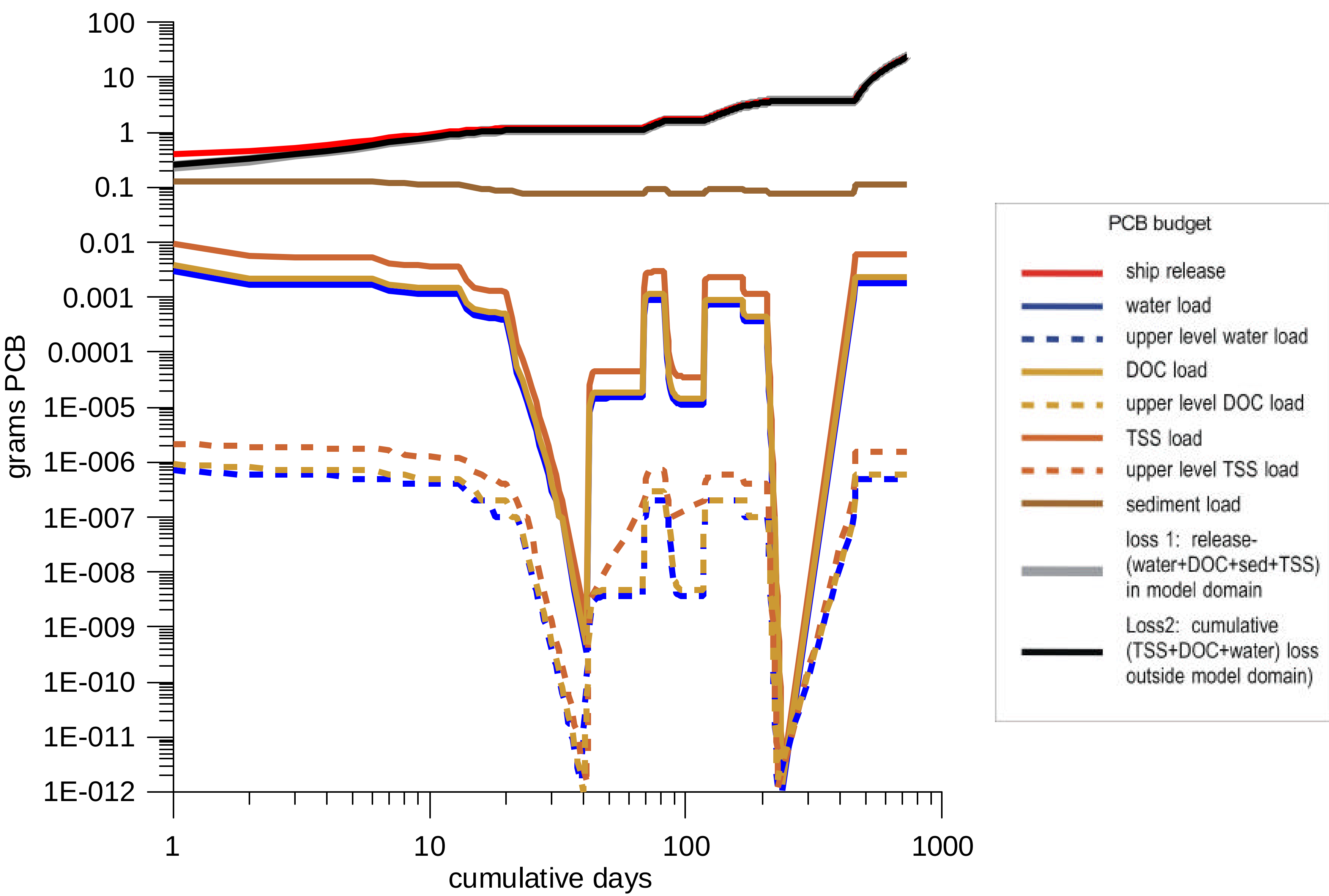


Figure C 22 – Nonachlorobiphenyl Concentrations at Distances of Highest Concentrations

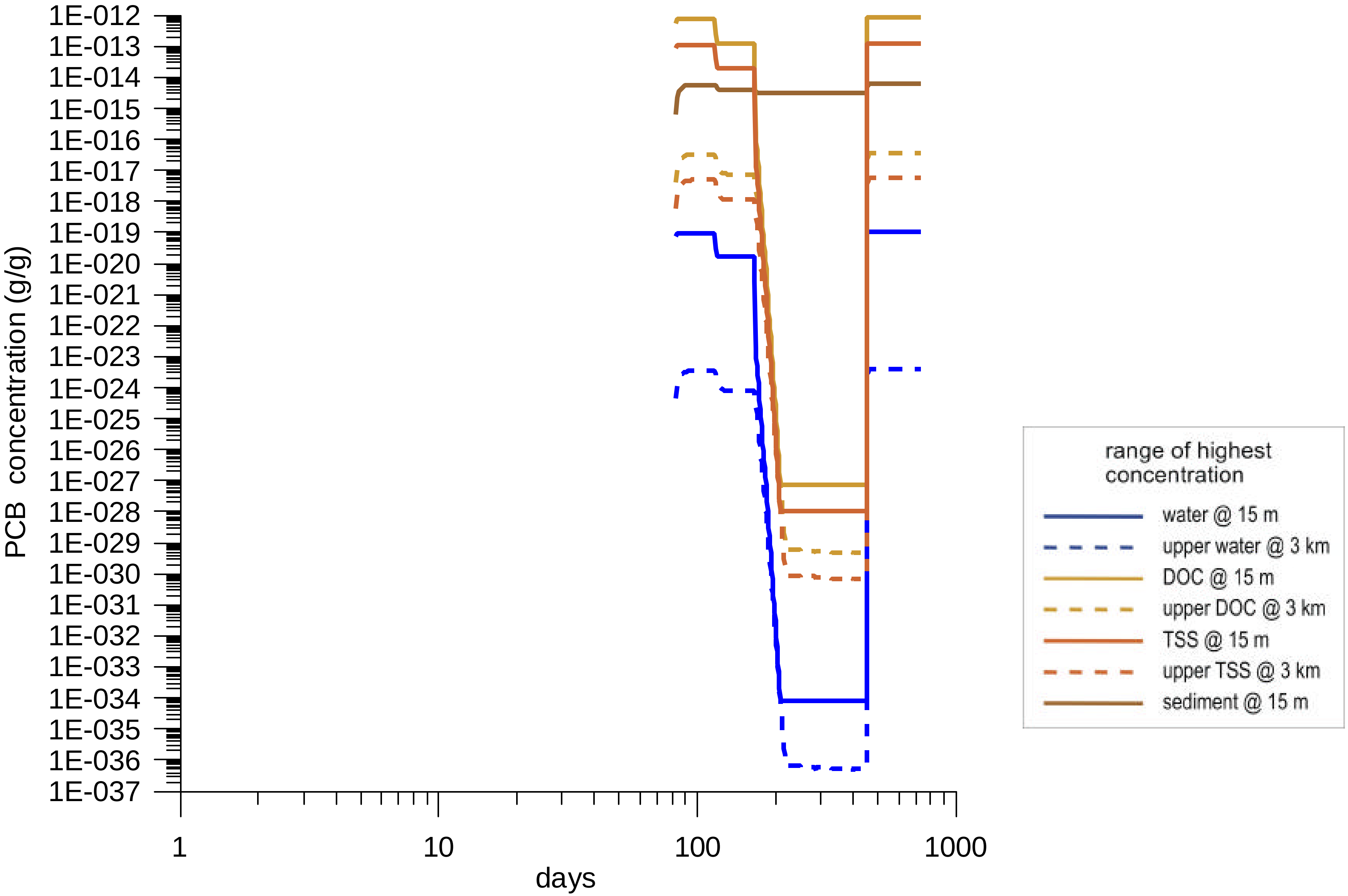


Figure C 23 –Nonachlorobiphenyl Concentrations and Total Released Mass inside the Ship

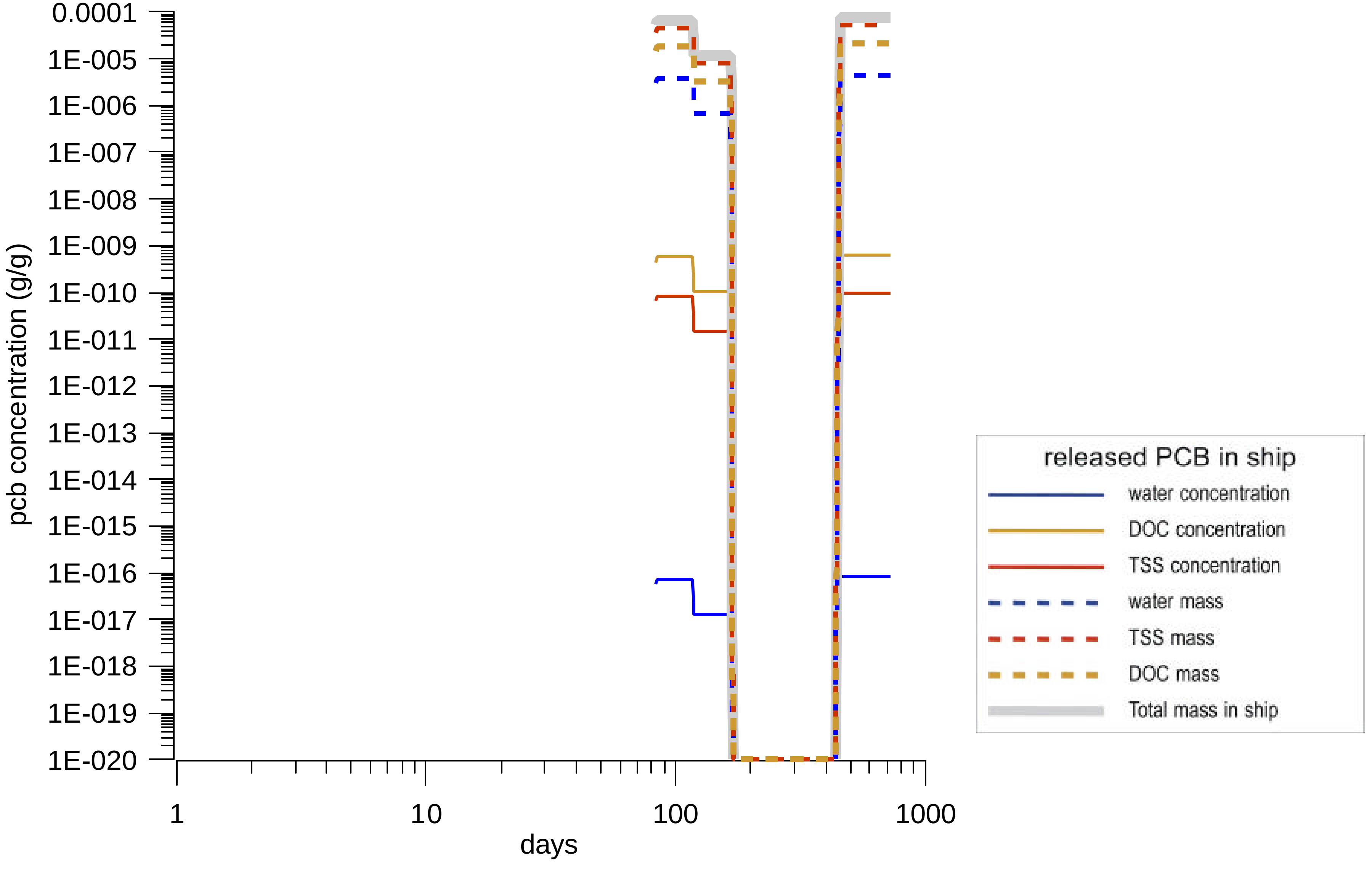


Figure C 24 – Nonachlorobiphenyl Mass Budget

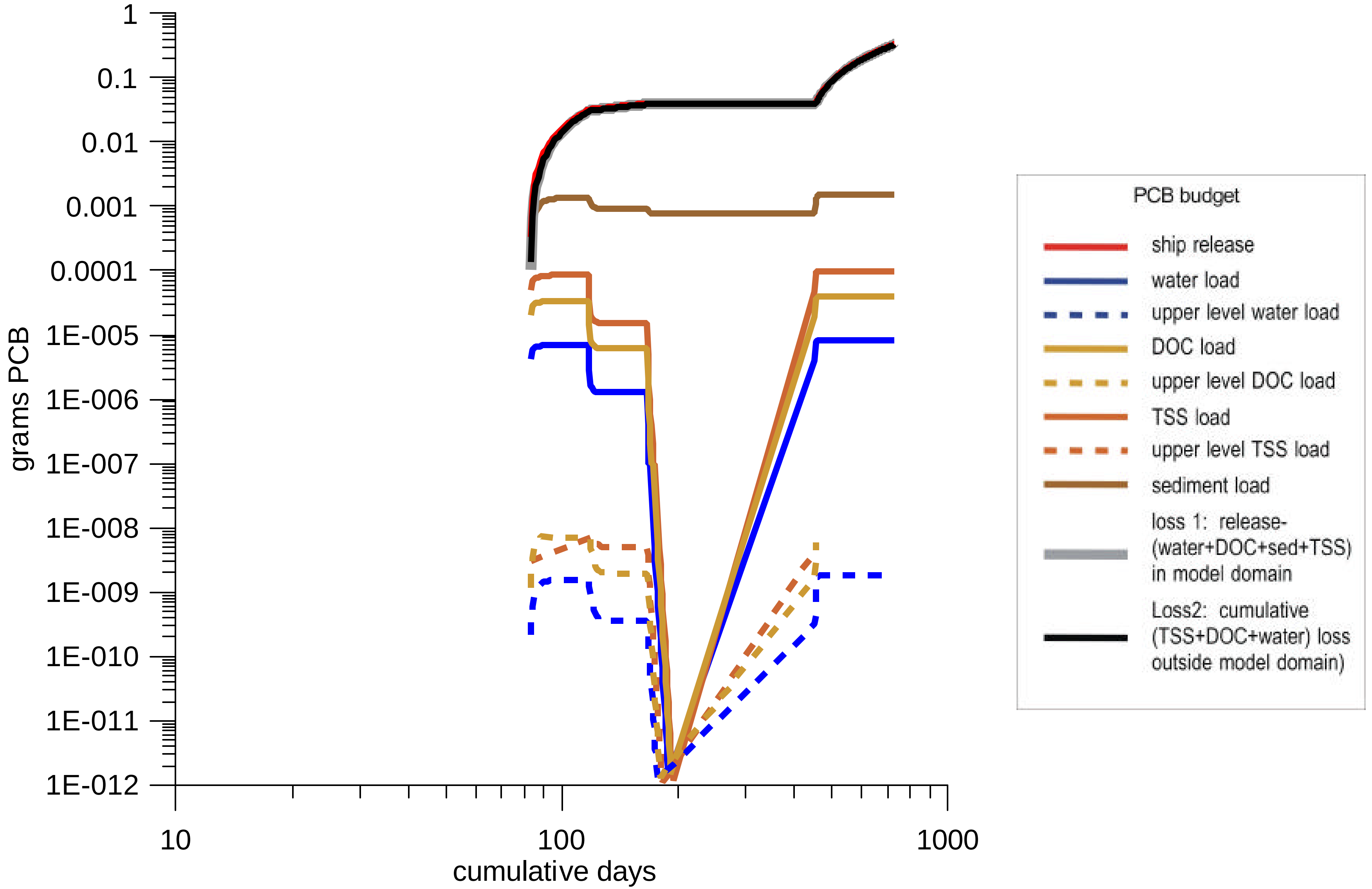


Figure C 25 – Decachlorobiphenyl Concentrations at Distances of Highest Concentrations

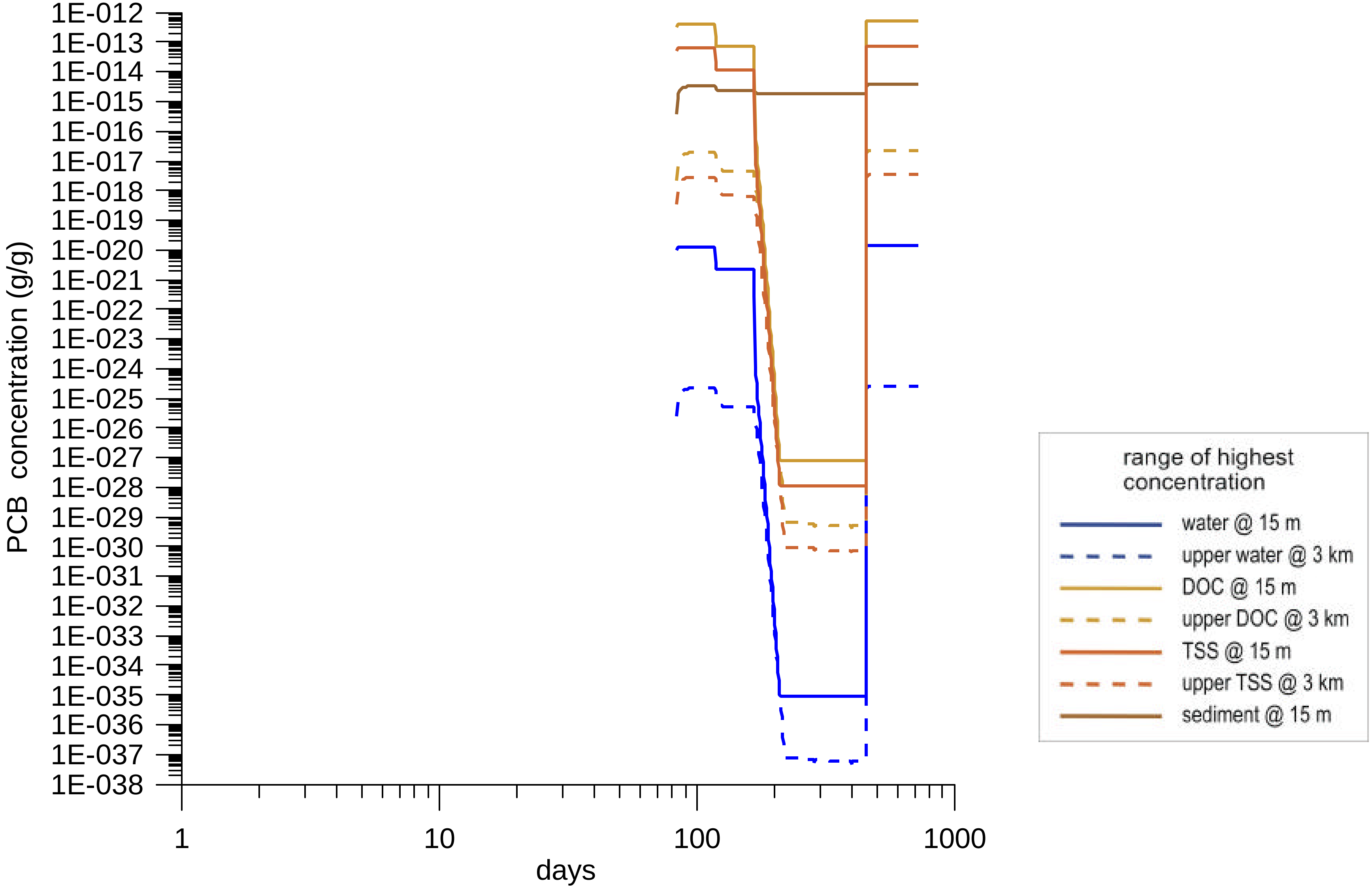


Figure C 26 – Decachlorobiphenyl Concentrations and Total Released Mass in the Ship

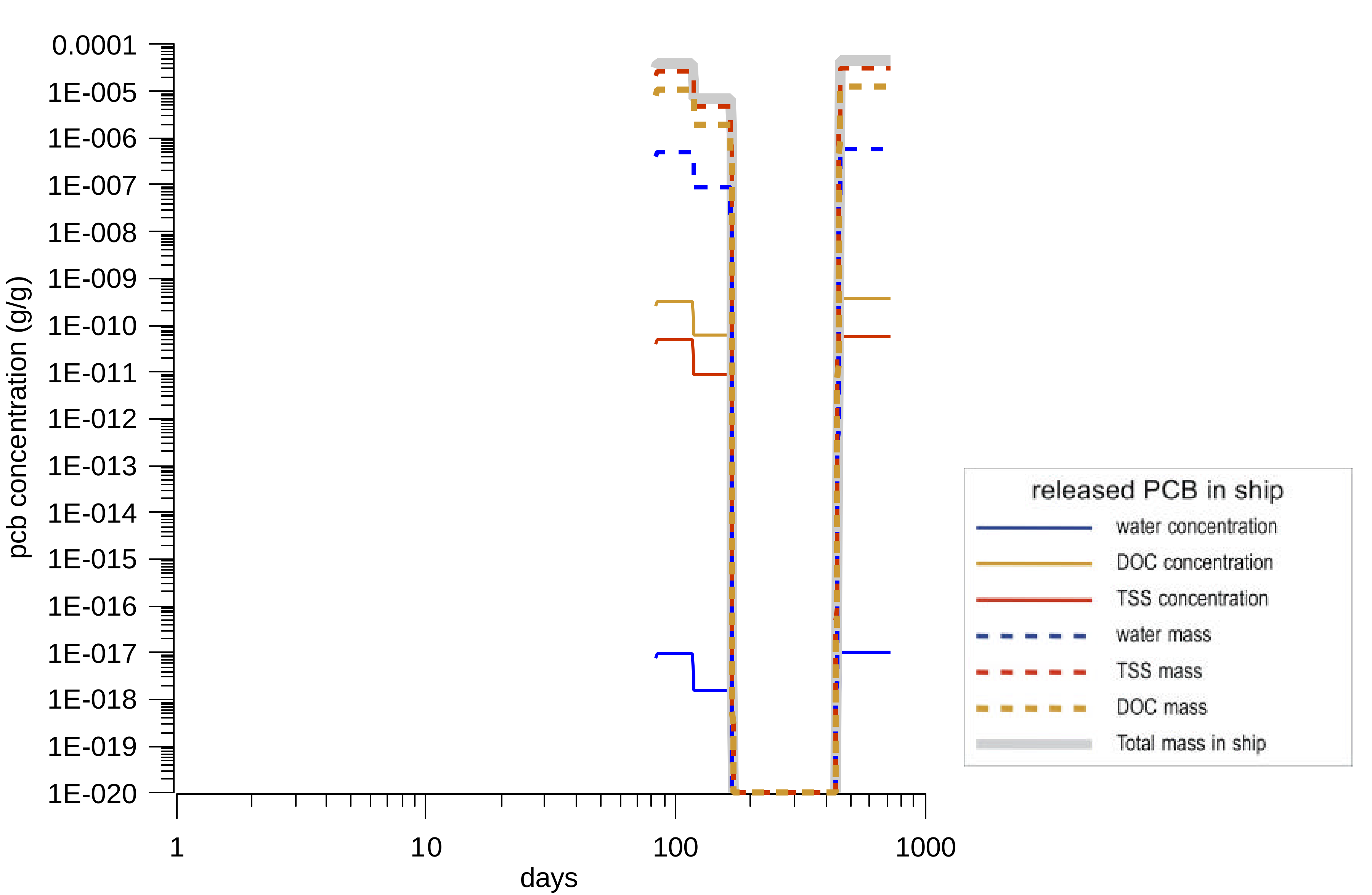


Figure C 27 – Decachlorobiphenyl Mass Budget

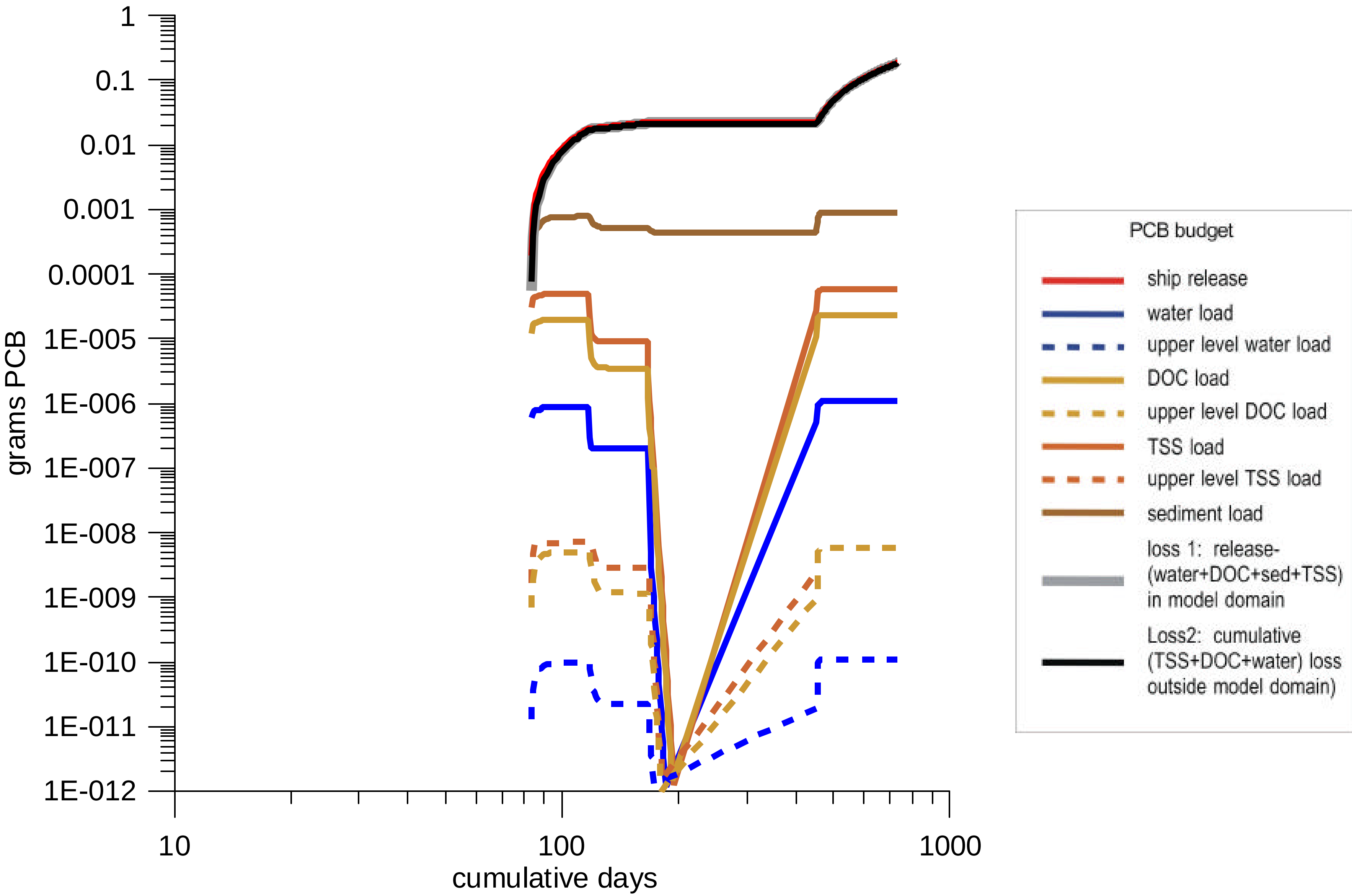


Figure C 28 – Total PCB Concentrations at Distances of Highest Concentrations

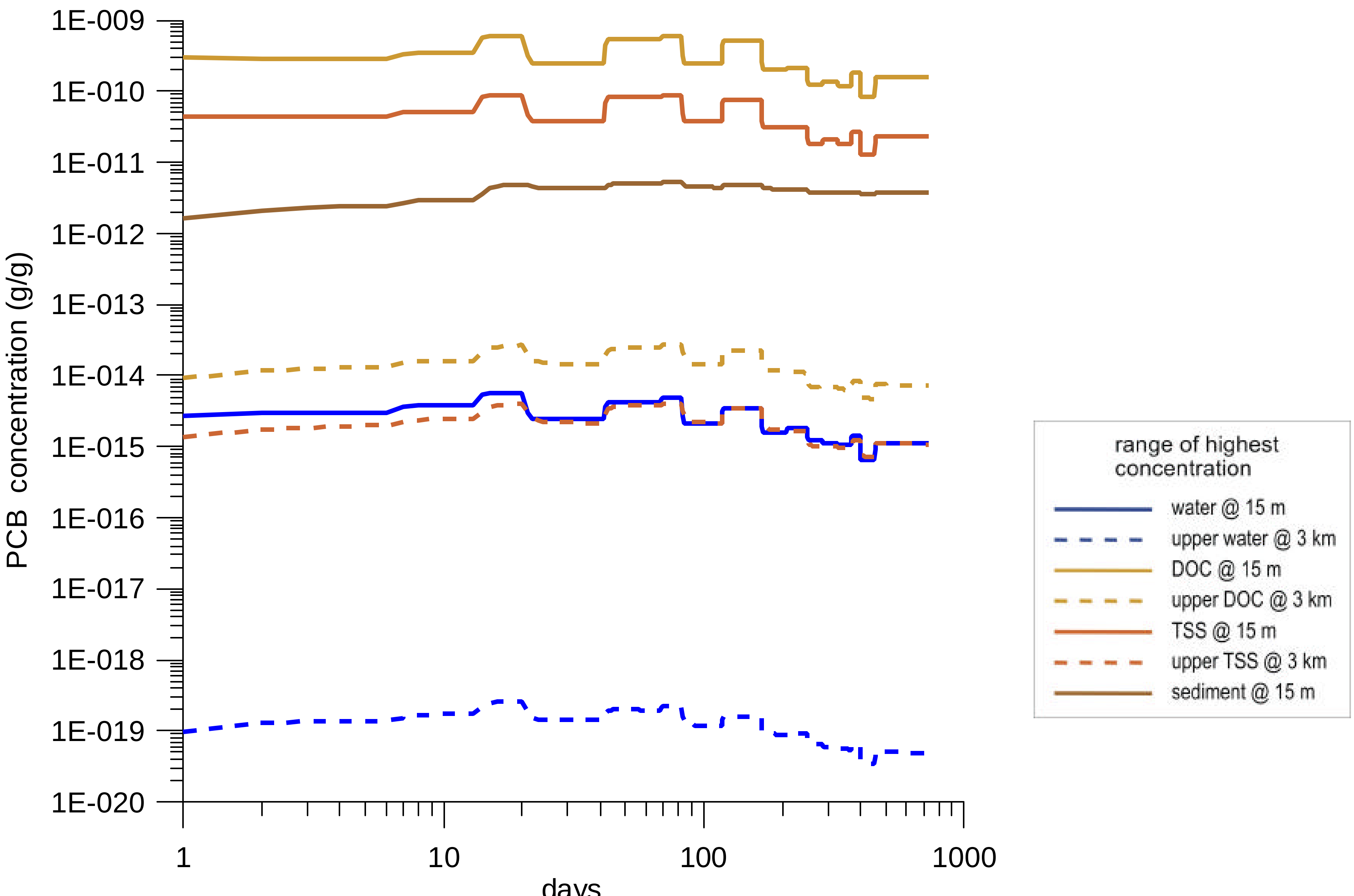


Figure C 29 – Total PCB Concentrations and Total Released Mass inside the Ship

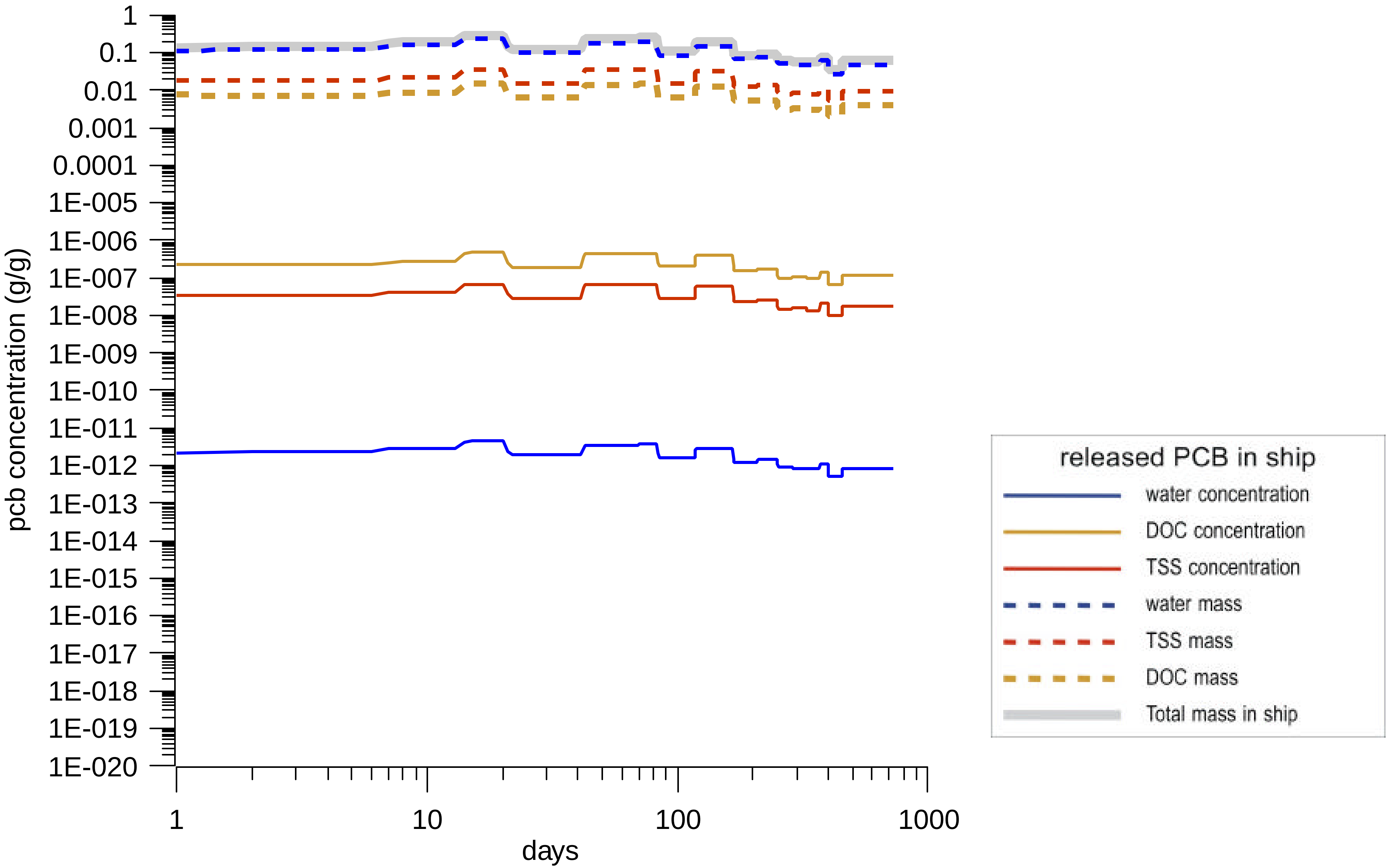


Figure C 30 – Total PCB Mass Budget

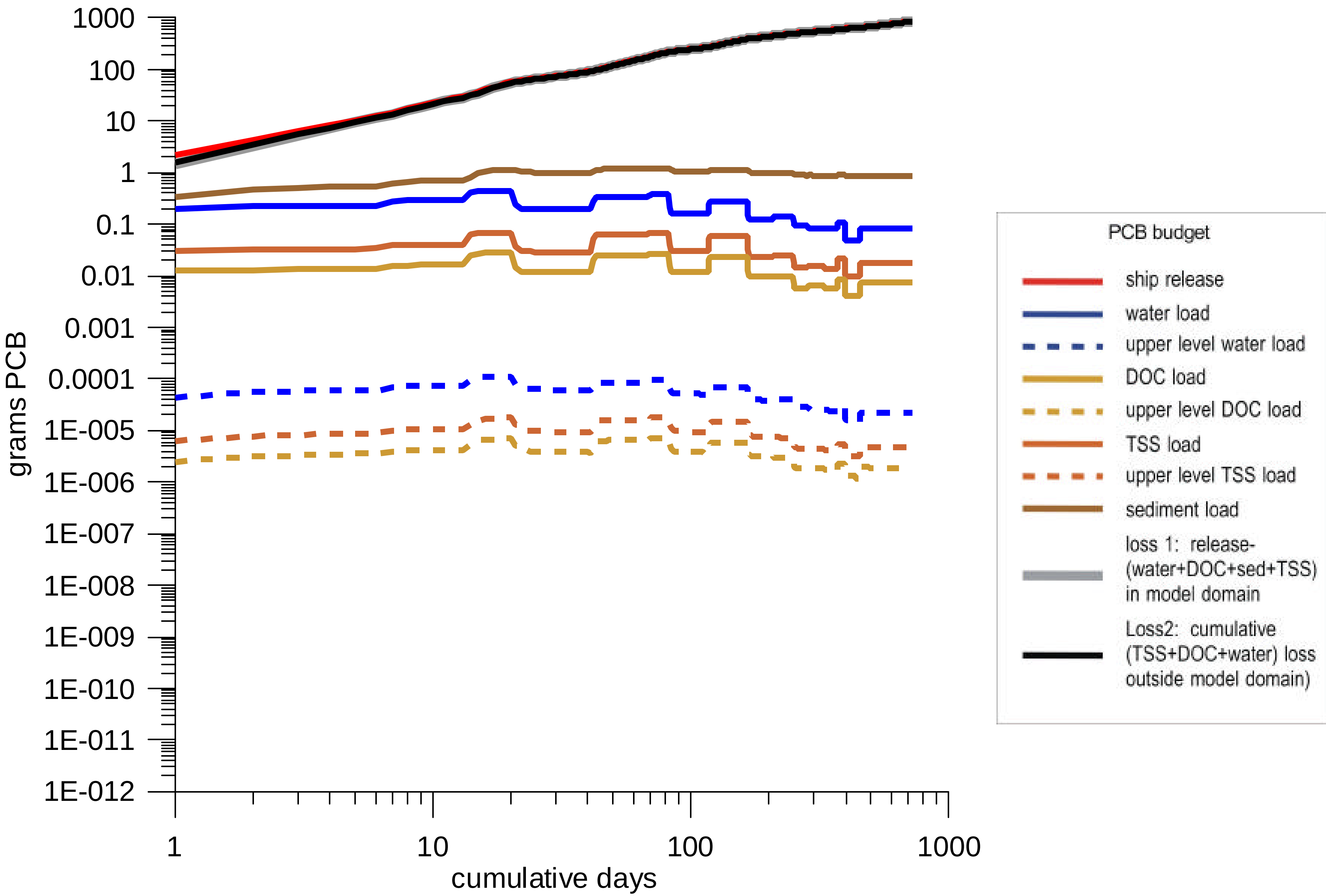


Figure C 31 –Table of PCB Homolog Release Rates used in the TDM

	Final Preparation Scenario, 72.6% BHI Removal	Sum of All Material Contributions Averaged over each Interval										
		ex-Oriskany 95% UCL Total Vessel Release Rate (g PCB/day)										
Leaching Time (days)	Leaching Interval (days)	Cl1-all	Cl2-all	Cl3-all	Cl4-all	Cl5-all	Cl6-all	Cl7-all	Cl8-all	Cl9-all	Cl10-all	tPCBs-all
0												
0.007	0.007	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.5E-02	0.0E+00	0.0E+00	0.0E+00	5.5E-02
1	1.163	0.0E+00	0.0E+00	2.0E-02	4.8E-01	4.5E-01	0.0E+00	3.2E-01	0.0E+00	0.0E+00	0.0E+00	1.3E+00
7	5.906	6.1E-05	1.7E-01	6.4E-02	8.3E-01	7.9E-01	1.2E-01	6.7E-02	0.0E+00	0.0E+00	0.0E+00	2.1E+00
14	7.007	0.0E+00	6.4E-02	5.6E-02	1.1E+00	1.2E+00	1.4E-01	4.6E-02	0.0E+00	0.0E+00	0.0E+00	2.6E+00
21	7.015	3.9E-05	3.8E-03	5.2E-02	1.3E+00	2.3E+00	3.4E-01	1.6E-02	0.0E+00	0.0E+00	0.0E+00	3.9E+00
42	21.129	3.4E-05	5.8E-03	2.6E-02	6.0E-01	9.2E-01	1.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E+00
69	27.074	8.0E-06	3.7E-03	2.2E-02	7.8E-01	1.8E+00	4.2E-01	5.8E-04	0.0E+00	0.0E+00	0.0E+00	3.0E+00
83	13.838	2.7E-05	1.0E-02	2.7E-02	8.4E-01	2.1E+00	3.8E-01	3.6E-02	0.0E+00	0.0E+00	0.0E+00	3.4E+00
118	34.997	2.5E-05	2.8E-03	1.7E-02	4.3E-01	8.4E-01	1.9E-01	4.5E-04	0.0E+00	9.1E-04	5.1E-04	1.5E+00
167	48.969	2.1E-05	5.1E-04	1.2E-02	5.7E-01	1.6E+00	4.1E-01	2.8E-02	0.0E+00	1.6E-04	9.1E-05	2.6E+00
209	42.026	1.8E-05	4.0E-04	1.0E-02	3.2E-01	6.5E-01	1.4E-01	1.4E-02	0.0E+00	0.0E+00	0.0E+00	1.1E+00
251	42.061	1.9E-05	2.2E-06	1.2E-02	3.7E-01	7.6E-01	1.5E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E+00
286	34.958	2.1E-05	2.5E-06	8.9E-03	3.1E-01	4.4E-01	6.9E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.3E-01
328	41.942	1.9E-05	1.2E-05	8.9E-03	2.2E-01	4.5E-01	1.1E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E-01
370	42.024	1.9E-05	1.7E-05	9.6E-03	2.6E-01	4.0E-01	8.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.5E-01
398	27.963	1.7E-05	3.8E-05	1.9E-02	3.1E-01	5.5E-01	1.5E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
454	56.240	1.5E-05	1.1E-05	1.1E-02	1.4E-01	2.4E-01	7.2E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.6E-01
730	275.681	1.4E-05	1.4E-01	1.0E-02	1.7E-01	3.2E-01	7.9E-02	7.3E-02	0.0E+00	1.1E-03	5.9E-04	8.0E-01
	Total Mass Released over 730 days (g PCB)	1.3E-02	4.1E+01	9.7E+00	2.3E+02	4.6E+02	1.0E+02	2.4E+01	0.0E+00	3.3E-01	1.9E-01	8.7E+02
	At end of Pulse, rate used from regression analysis/PRAM is significantly higher than final empirical rate											
	Average based predominantly on PRAM rates from regression analysis, but slight overlap with final empirical pulse interval rate for some materials											
	ex-Oriskany Loading by Homologue (PCBs onboard using CACI Report and Homologue distributions from Leach Rate Study materials)											
		Cl1	Cl2	Cl3	Cl4	Cl5	Cl6	Cl7	Cl8	Cl9	Cl10	tPCBs
		2.4E-04	3.4E-03	3.0E-01	5.9E+01	2.8E+02	1.8E+02	4.8E+01	4.8E-01	5.9E-02	2.2E-02	5.6E+02
		Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg

Final Report

Polychlorinated biphenyls (PCB) Source Term Estimates

for ex-ORISKANY (CVA 34)

Rev. 4

December 7, 2004

Prepared for

Program Executive Office (Ships)
Navy Inactive Ships Program (PMS 333)
1333 Isaac Hull Avenue, SE
Washington, DC 20376-2101

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Table of Contents

Introduction

The FY04 National Defense Authorization Bill (HR 1588 Sec 1013) permits decommissioned ships stricken from the Naval Vessel Register to be transferred to States for use as artificial reefs[1]. This new artificial reefing authority allows the Navy's Inactive Ships Program under PEO SHIPS to reduce their inventories of unneeded vessels.

The Navy's program objective is to reduce the size of the inactive ships inventory in a cost-effective and environmentally sound manner. The Navy will accomplish the environmental remediation of transferred vessels in accordance with draft EPA Best Management Practices[2]. The purpose of this report, determining the amount of PCB containing materials aboard the subject vessel, supports those objectives.

The vessel, the first warship offered for transfer by the Navy for sinking as an artificial reef, is the ex-*Oriskany* (CVA 34).

Background

USS *Oriskany*, a 27,100 ton *Ticonderoga* class aircraft carrier, was built at the New York Navy Yard. Though she was launched in October 1945, construction was suspended in August 1947 and she was completed to a revised design that was also used in modernizing several other ships of the *Essex* and *Ticonderoga* classes[3]. Designated SCB-27, the modernization was very extensive, requiring two years for each carrier. *Oriskany* became the prototype. To handle much heavier, faster aircraft, flight deck structure was massively reinforced. Stronger elevators, much more powerful catapults, and new arresting gear were installed.

A distinctive new feature was a new island. Ready rooms were moved to below the hangar deck, with a large escalator on the starboard side amidships to move airmen up to the flight deck. Internally, aviation gasoline storage was increased by nearly half and its pumping capacity enhanced. Also improved were electrical generating power, fire protection, and weapons stowage and handling facilities. All this added considerable weight: displacement increased by some twenty percent. *Essex* was the second carrier to be modernized to the SCB-27A design[4].

Commissioned in September 1950, *Oriskany* deployed to the Mediterranean Sea between May and October 1951 and steamed around Cape Horn to join the Pacific Fleet in May 1952. She made one Korean War combat cruise, from September 1952 to May 1953.

Oriskany was out of commission from January 1957 until March 1959, during which time she was modernized with an angled flight deck, steam catapults, an enclosed "hurricane" bow and many other improvements that permitted safer operation of high-performance aircraft. In 1961, she became the first aircraft carrier to be fitted with the revolutionary Naval Tactical Data System (NTDS).

After twenty-six years of service, USS *Oriskany* was decommissioned in September 1976. She was stricken from the Naval Vessel Register in July 1989 and sold for scrapping in 1994, but was repossessed by the US Government in 1997. *Oriskany* is presently being prepared for use as an artificial reef at Texas Dock and Rail Company in Corpus Christi, Texas by Resolve Marine. The Navy is pursuing a risked-based disposal approval under 40 CFR 761 from the EPA before transferring the ship to the State of Florida for use as an artificial reef by the Florida Fish and Wildlife Conservation Commission. The following report provides estimates of PCB-containing material quantities found aboard the vessel to assist Navy and EPA authorities in determining that risk. *Oriskany* will eventually be sunk, and become part of the Escambia East Large Area Artificial Reef Site, off Pensacola.

Figure 1 *Oriskany* at Texas Dock & Rail

Methodology

PCB-containing materials were identified aboard *Oriskany* through PMS 333's routine sampling protocol for vessels during the inactivation process[5, 6]. Materials/components found to contain PCBs at some concentration include paints, rubber products, electrical cable insulation, bulkhead insulation, ventilation gaskets, and lubricants. Therefore, the scope of this study is limited to quantifying, by the best available means, the amount of these materials aboard *Oriskany* and calculating the PCBs available in these materials that could be potentially released into the environment if left aboard (the PCB source term).

Wherever possible, data from the *Oriskany* was used in the quantification process. PCB concentration data from samples collected aboard the ship were used exclusively[5, 6, and 7]. The ship was also visually inspected and onsite personnel involved in the preparation of the ship were interviewed by CACI personnel to verify the presence of targeted materials, define possible remediation/salvage scenarios, and to ensure no other materials historically found to contain PCBs on Navy ships (such as impregnated felt) were aboard *Oriskany*.

Where weight/quantity data was not directly available for *Oriskany*, data from surrogate vessels were used to approximate conditions found on *Oriskany* as closely as possible. Surrogate vessels were selected using the following criteria: 1. data readily available, 2. data from the same class (*Essex*/*Ticonderoga* Class), 3. data from another aircraft carrier, 4. data from a large combatant built in the same era. Fortunately, information unavailable for *Oriskany* necessary to quantify the material aboard was found for the

Essex (CV-9) and the *Lexington* (CV-16). Specifically, a microfiche copy of the Final Weight Report (FWR) for USS *Essex*[8] was acquired from NSWC Carderock Code 224, and the fan list for USS *Lexington* was acquired from John J. McMullen Associates. The use of these documents, along with other estimating assumptions will be discussed in greater detail in the Results section of this report.

After determining the initial (as built) quantity of a subject material, the material weight (in pounds) was adjusted by various factors to approximate as closely as possible the existing conditions aboard *Oriskany*. These correction factors include "growth rates" for materials that accumulate over the life cycle of the vessel, remediation (reduction) ratios for materials removed during preparation, or conservative multipliers to account for undocumented material quantities.

The total estimated existing material weights were then multiplied by the mean and 95% upper confidence limit (UCL) PCB concentration of all samples of a given material to derive the weight of PCBs attributable to each type of PCB-containing material within the scope of the study. These Source Terms were then totaled to derive the mean and 95% UCL of the mean Total Weight of PCBs.

Results

Bulkhead Insulation

PMS 333 collected thirty-two samples of bulkhead insulation for PCB analysis. All samples were analyzed by Puget Sound Naval Shipyard. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

Table 1 Bulkhead Insulation Sample Results

Sample #	MDL ppm	PCBs ppm	Calculated PCBs ppm
95PS00019-001	5	53	53
95PS00019-002	5	6100	6100
95PS00019-003	5	60	60
95PS00019-004	5	45	45
95PS00019-005	5	<5	2.5
95PS00019-006	5	5.9	5.9
95PS00019-007	5	<5	2.5
95PS00019-008	5	<5	2.5
95PS00019-009	5	<5	2.5
95PS00019-010	5	<5	2.5
95PS00019-011	5	11	11
95PS00019-012	5	<5	2.5
95PS00019-013	5	<5	2.5

95PS00019-014	5	18	18
95PS00019-015	5	7.4	7.4
95PS00019-016	5	<5	2.5
95PS00019-017	5	6.4	6.4
95PS00019-018	5	7.3	7.3
95PS00019-019	5	5.5	5.5
95PS00019-020	5	6.6	6.6
95PS00019-021	5	130	130
95PS00019-022	5	39	39
95PS00019-023	5	320	320
95PS00019-024	5	15	15
95PS00019-025	5	6.9	6.9
95PS00019-026	5	<5	2.5
95PS00019-027	5	11	11
95PS00019-028	5	<5	2.5
95PS00019-029	5	<5	2.5
95PS00019-030	5	<5	2.5
95PS00019-031	5	<5	2.5
95PS00019-032	5	<5	2.5
		Mean	215.1
		95% UCL	587.7

The estimated quantity of bulkhead insulation aboard *Oriskany* was determined from a review of the *Essex* FWR listing for Group 22 d-2 “Bulkheads” and 49 individual weight entries were summed to calculate a total weight of 115, 695 lbs of bulkhead insulation. This weight is assumed to be equivalent to the weight aboard *Oriskany* with no correction.

Figure 2 Typical space with peeling paint and bulkhead insulation.

Rubber Products

PMS 333 collected 30 samples of rubber products (door gaskets, pipe hangers, mounts, etc.) for PCB analysis. Twenty-nine samples were analyzed by Puget Sound Naval Shipyard and one sample was analyzed by Norfolk Naval Shipyard. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

Table 2 Rubber Products Sample Results

Sample #	MDL ppm	PCBs ppm	Calculated PCBs ppm
95PS00032-001	5	32	32
95PS00032-002	5	10	10
95PS00032-003	5	24	24
95PS00032-004	5	130	130
95PS00032-005	5	6.5	6.5
95PS00032-006	5	54	54
95PS00032-007	5	29	29
95PS00032-008	5	14	14
95PS00032-009	5	<5	2.5
95PS00032-010	5	19	19
95PS00032-011	5	8.9	8.9
95PS00035-015	5	12	12
95PS00035-016	5	58	58
95PS00035-017	5	<5	2.5
95PS00035-018	5	110	110
95PS00035-019	5	<5	2.5
95PS00035-020	5	17	17
95PS00035-021	5	46	46
95PS00035-022	5	13	13
95PS00035-023	5	<5	2.5
95PS00035-024	5	28	28
95PS00035-025	5	12	12
95PS00035-026	5	110	110
95PS00035-027	5	92	92
95PS00035-028	5	39	39
95PS00035-029	5	120	120
95PS00035-030	5	33	33
95PS00035-031	5	49	49
95PS00035-032	5	42	42
91NN00999-044	1	<1	0.5
		Mean	37.3
		95% UCL	50.9

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The estimated quantity of rubber products aboard *Oriskany* was determined by a review of the *Essex* FWR listing for Group 36 "Doors and Hatches". These weights are assumed to be directly equivalent to *Oriskany*, with the following correction. There was no available weight data for other rubber products, so a conservative multiplier of two was applied to the calculated total weight of door/hatch gaskets (the most abundant source of rubber material) to account for unquantifiable rubber products.

The weight of door, hatch, manhole, and scuttle gaskets was derived by counting the quantity of each category from the Group 36 listing. An average weight of gasket for each category was derived by calculating the average perimeter of each closure size and multiplying that perimeter by 0.34 lb/ft, the weight of MIL-R-900 standard rubber gasket stock.

Table 3 Door Gasket Weights

		Door Sizes		
L in	**W in**	**Perim. In**	**ft**	**lbs**
18	36	108	9.0	3.1
26	45	142	11.8	4.0
26	54	160	13.3	4.5
26	57	166	13.8	4.7
26	66	184	15.3	5.2
30	66	192	16.0	5.4
			Average	4.5

Table 4 Hatch Gasket Weights

		Hatch Sizes		
L in	**W in**	**Perim. In**	**ft**	**lbs**
24	36	120	10.0	3.4
30	30	120	10.0	3.4
30	36	132	11.0	3.7
30	48	156	13.0	4.4
30	60	180	15.0	5.1
36	42	156	13.0	4.4
36	60	192	16.0	5.4
36	72	216	18.0	6.1
48	48	192	16.0	5.4
60	60	240	20.0	6.8
			Average	4.8

Table 5 Manhole Gasket Weights

Manhole Sizes				
L in	W in	Perim. In	ft	lbs
15	18	66	5.5	1.9
15	23	76	6.3	2.2
			Average	2.0

Table 6 Scuttle Gasket Weights

Scuttle Sizes				
Dia. In		Perim. In	ft	lbs
18		56.5	4.7	1.6
21		66.0	5.5	1.9
			Average	1.7

Table 7 Rubber Product Weight Summary

Weight Summary Rubber Products							
Gaskets	Doors	Hatches	M.H.	Scuttles	Multiplier		
Count	844	193	532	88			
Avg. Lb/gasket	4.5	4.8	2.0	1.7			
Total lbs	3794.2	931.8	1070.2	152.7	2	11898.0	**Grand Total lbs**

The result of the analysis showed 1,567 closures with a corresponding weight of gaskets of 5,949 lbs. The conservative multiplier of two resulted in a total estimated weight of rubber product aboard *Oriskany* of 11, 989 lbs.

Paints

PMS 333 collected five samples of paint products for PCB analysis. These samples were analyzed by Puget Sound Naval Shipyard. ESCO Marine collected two composite samples of removed paint chips from *Oriskany* that were analyzed by Analab. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

Table 8 Paint Sample Results

Sample #	MDL ppm	PCBs ppm	Calculated PCBs ppm
Analab 655039	1	24.4	24.4
Analab 655040	1	15.2	15.2
95PS0032-012	5	<5	2.5
95PS0032-013	5	<5	2.5
95PS0032-014	5	<5	2.5
95PS0032-015	5	28	28
95PS0032-016	5	5.8	5.8
		Mean	11.6
		95% UCL	19.7

The estimated quantity of paint aboard *Oriskany* was determined from a review of the *Essex* FWR listing for Group 24 a "Paints and Varnishes" and after non-paint entries were eliminated, the remaining entries were summed to calculate a total weight of 298,999 lbs of paint. This weight is assumed to be equivalent to the weight aboard *Oriskany* with no correction.

Electrical Cable Insulation

PMS 333 collected 59 samples of electrical cable/wire insulation for PCB analysis. Fifty samples were analyzed by Puget Sound Naval Shipyard and nine samples were analyzed by Norfolk Naval Shipyard. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

Figure 3 Cable trays in auxiliary machine room.

Table 9 Cable Insulation Sample Results

Sample #	MDL ppm	PCBs ppm	Calculated PCBs ppm
95PS00034-001	5	110	110
95PS00034-002	5	580	580
95PS00034-003	5	10	10
95PS00034-004	5	22	22
95PS00034-005	5	9.5	9.5
95PS00034-006	5	80	80
95PS00034-007	5	67	67
95PS00034-008	5	6.1	6.1
95PS00034-009	5	38	38
95PS00034-010	5	6.2	6.2
95PS00034-011	5	400	400
95PS00034-012	5	140	140
95PS00034-013	5	290	290
95PS00034-014	5	110	110
95PS00034-015	5	2200	2200
95PS00034-016	5	<5	2.5
95PS00034-017	5	56	56
95PS00034-018	5	12000	12000
95PS00034-019	5	94	94
95PS00034-020	5	85	85
95PS00034-021	5	37	37
95PS00034-022	5	24	24
95PS00034-023	5	23	23
95PS00034-024	5	12	12
95PS00034-025	5	11000	11000
95PS00034-026	5	63	63
95PS00034-027	5	100	100
95PS00034-028	5	13	13
95PS00034-029	5	45	45
95PS00034-030	5	29000	29000
95PS00034-031	5	80	80
95PS00034-032	5	150	150
95PS00035-001	5	42	42
95PS00035-002	5	290	290
95PS00035-003	5	19000	19000
95PS00035-004	5	71	71
95PS00035-005	5	30	30
95PS00035-006	5	38	38
95PS00035-007	5	85	85
95PS00035-008	5	180	180
95PS00035-009	5	95	95
95PS00035-010	5	67	67

95PS00035-011	5	59	59
95PS00035-012	5	18	18
95PS00035-013	5	65	65
95PS00035-014	5	110	110
95PS00032-017	5	580	580
95PS00032-018	5	150	150
95PS00032-019	5	140	140
95PS00032-020	5	10000	10000
91NN00999-046	1	<1	0.5
91NN00999-048	1	29	29
91NN00999-054	1	78	78
91NN00999-057	1	15	15
91NN00999-066	1	33	33
91NN00999-067	1	13	13
91NN00999-080	1	23	23
91NN00999-082	1	8	8
91NN00999-085	1	70	70
		Mean	1493.9
		95% UCL	2766.0

The estimated quantity of electrical cable insulation aboard *Oriskany* was determined from a review of the *Essex* FWR listing for Group 44 "Electrical Plant" The total reported weight of the electrical plant was listed as 1,551,498 lbs. NSWCCD Code 244 conducted a review of other CV/CVN weight reports and determined the cable to electrical plant weight ratio to be 36%. Using this ratio, the weight of cable from the FWR calculates to 558,539.3 lbs. A study of the Navy Cable Inventory conducted by Westinghouse MTD found that the percentage of insulation in any given quantity of bulk cable is 72.26% for a typical combatant. Multiplying the estimated weight of cable by the insulation percentage gives an estimated weight of cable insulation of 403,600.5 lbs. This weight is assumed to be equivalent to the weight aboard *Oriskany* with no additional correction.

Ventilation Gaskets

The visual inspection of the Oriskany in Corpus Christ, TX revealed that no ventilation gaskets were impregnated felt material. Of all gaskets observed, 95% were rubber, 5% were compressed hard fiber material. PMS 333 collected 34 samples of ventilation gasket material for PCB analysis. All samples were analyzed by Norfolk Naval Shipyard. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

Table 10 Ventilation Gasket Sample Results

Sample #	MDL ppm	PCBs ppm	Calculated PCBs ppm
91NN00999-045	1	<1	0.5
91NN00999-047	1	<1	0.5
91NN00999-049	1	7	7
91NN00999-050	1	<1	0.5
91NN00999-051	1	<1	0.5
91NN00999-052	1	<1	0.5
91NN00999-053	1	<1	0.5
91NN00999-055	1	49	49
91NN00999-056	1	<1	0.5
91NN00999-058	1	22	22
91NN00999-059	1	6	6
91NN00999-060	1	5	5
91NN00999-061	1	6	6
91NN00999-062	1	210	210
91NN00999-063	1	8	8
91NN00999-064	1	11	11
91NN00999-065	1	50	50
91NN00999-068	1	13	13
91NN00999-069	1	33	33
91NN00999-070	1	<1	0.5
91NN00999-071	1	<1	0.5
91NN00999-072	1	5	5
91NN00999-073	1	41	41
91NN00999-074	1	<1	0.5
91NN00999-075	1	78	78
91NN00999-076	1	<1	0.5
91NN00999-077	1	<1	0.5
91NN00999-078	1	63	63
91NN00999-079	1	<1	0.5
91NN00999-081	1	35	35
91NN00999-083	1	<1	0.5
91NN00999-084	1	<1	0.5
91NN00999-086	1	25	25
91NN00999-087	1	15	15
		Mean	20.3
		95% UCL	33.5

A review of the fan list of *Lexington* (CV 16) determined that, based on an algorithm developed by naval ventilation engineers using the number and size of fans, the ventilation system contains 6700 flanges. The average gasket weight per flange is 0.4

lbs. This results in a total ventilation gasket weight of 2680 lbs. This weight is assumed to be equivalent to the weight aboard *Oriskany* with no additional correction.

Lubricants

PMS 333 collected 11 samples of lube oils and greases for PCB analysis. Ten samples were analyzed by Puget Sound Naval Shipyard and one sample was analyzed by Norfolk Naval Shipyard. Results reported as less than the method detection limit (MDL) were calculated as one half of the MDL for the purpose of determining the mean PCB concentration for the material.

Table 11 Lubricant Sample Results

Sample #	MDL ppm	PCBs ppm	Calculated PCBs ppm
91NN00999-001	1	<1	0.5
95PS00029-001	1	150	150
95PS00029-002	1	230	230
95PS00029-003	1	<1	0.5
95PS00029-004	1	<1	0.5
95PS00029-005	1	4	4
95PS00029-006	1	<1	0.5
95PS00029-007	1	67	67
95PS00029-008	1	100	100
95PS00029-009	1	<1	0.5
95PS00029-010	1	110	110
		Mean	60.3
		95% UCL	106.8

The estimated quantity of lubricants aboard *Oriskany* was determined from a review of the *Essex* FWR listing for Group 53 “Fuel, Gasoline, and Lube” and, after fuels and gasoline entries were eliminated, the remaining entries were summed to calculate a total weight of 208,104 lbs of lube oil. The weight of miscellaneous lubricants (such as greases), are assumed to be an insignificant percentage of the total weight of other lube oil stores. This weight is assumed to be equivalent to the weight aboard *Oriskany* with no correction.

Baseline PCB Source Terms

Extending the as-built estimated weights for the subject materials to reflect present day conditions aboard *Oriskany* requires adjusting the as-built (FWR) derived estimates to reflect lifecycle increases in materials, where appropriate. If available, Navy standard growth rate have been applied.

For example, Navy material and weight experts estimate that the thickness of paint on vessels (and therefore weight), with repeated painting, stripping, and repainting activities, increases by a factor of 3 over a 30-year life cycle. This is in contrast with rubber products and bulkhead insulation, which is relatively static, being removed and replaced as necessary in a one for one changeout, with no net change in quantity. Electrical and ventilation systems can experience modest growth, but generally as a result of installation of new systems or modification/modernization programs. Accordingly, a 20% growth rate has been applied to the ventilation gasket and electrical cable insulation weights in proportion to the 20% increase in overall ship displacement as a result of SCB-27A modernization program. An additional 10% is included to the cable growth rate to account for the Naval Tactical Data System added in 1961. Lube oils are limited by the original design capacities of the systems they occupy.

The baseline PCB source terms, below, reflect lifecycle growth, but do not include any reductions as a result of the preparation of the vessel for use as an artificial reef.

Table 12 Baseline Source Terms

Material	FWR Wt (lbs)	30yr Growth	Avg.PCB Conc. ppm	95% UCL	Lbs PCB	95% UCL lbs
Paints	298999	3	11.6	19.7	10.4	17.7
Bulkhead Insulation	115695	1	215.1	587.7	24.9	68.0
Rubber Products	11898	1	37.3	50.9	0.4	0.6
Cable Insulation	403600	1.3	1493.9	2766.0	783.8	1451.3
Vent. Gaskets	2680	1.2	20.3	33.5	0.1	0.1
Lubricants	208140	1	60.3	106.8	12.6	22.2
				Total	832.2	1559.9

Preparation Scenario

The following source term table reflects possible reductions in PCB loading due to removal of items as part of the preparation process. The scenario assumes that 100% of all lubricants will be removed, 5% of the paint (flaking surfaces), 72.6% of the bulkhead insulation (Navy contracted to remove 42 tons of insulation), and 10% cable salvage. No significant removal of rubber products or ventilation gaskets is anticipated.

Table 13 Preparation Scenario Source Terms

Scenario- 100% Lubricants, 5% Paint, 72.6% BLKHD Ins. & 10% Cable Removal								
Material	**Est. Wt (lbs)**	**30yr Growth**	**Avg.PCB Conc. ppm**	**95% UCL ppm**	**Lbs PCB**	**Remaining**	**lbs PCB**	**95% UCL lbs**
Paints	298999	3	11.6	19.7	10.4	95%	9.8	16.8
Bulkhead Insulation	115695	1	215.1	587.7	24.9	27.4%	6.8	18.6
Rubber Products	11898	1	37.3	50.9	0.4	100%	0.4	0.6
Cable Insulation	403600	1.3	1493.9	2766.0	783.8	90%	705.5	1306.1
Vent. Gaskets	2680	1.2	20.3	33.5	0.1	100%	0.1	0.1
Lubricants	208140	1	60.3	106.8	12.6	0%	0.0	0.0
						Total	722.6	1342.3

The Preparation Scenario reflects the best available information to date with regard to the material expected to be removed in the preparation process. The EPA Best Management Practices guidance requires 100% removal of lube oils. Based on paint chip removal tonnage reported at the 50% conference[9] (9.38 LT removed prior to the conference date), it is estimated that at project completion 22 LT or 44, 000 lbs of paint chips (5% of the total weight) will have been removed. Contractor and SUPSHIP project personnel report 72.6% of the bulkhead insulation removed and estimate 10% of the electrical cable will be removed as a result of preparation activities.

Conclusions

The estimate shows the PCB source term related to electrical cable accounts for 95% of the total PCB loading of *Oriskany*. The next largest contributor, bulkhead insulation, only accounts for 3% of the total PCB load. Moreover, if paint, rubber products, and ventilation gaskets were addressed in terms of a bulk product disposal, they would be unregulated based on their mean concentration, and rubber would only be above regulatory limits at the very conservative 95% UCL of the mean concentration.

References

[1] Title 10 U.S.C § 7306b SEC. 1013. AUTHORIZE TRANSFER OF VESSELS STRICKEN FROM THE NAVAL VESSEL REGISTER FOR USE AS ARTIFICIAL REEFS.

[2] Press Release, "New Authority provides Navy's Inactive Ships for use as State," Naval Sea Systems Command, Public Affairs Office, December 8, 2003, http://www.navsea.navy.mil/newswire_content.asp?txtDataID=10039&txtTypeID=2

[3] Website: *Dictionary of American Naval Fighting Ships* Department of the Navy Naval Historical Center, 805 Kidder Breese SE -- Washington Navy Yard, Washington DC 20374-5060 http://history.navy.mil/danfs/o4/oriskany.htm

[4] Webpage: *SCB-27 modernization of Essex/Ticonderoga class aircraft carriers, (CV 9-12, 14-16, 18-20, 31, 33-34, 38-39)*, Department of the Navy Naval Historical Center, 805 Kidder Breese SE -- Washington Navy Yard, Washington DC 20374-5060, http://www.history.navy.mil/photos/usnshtp/cv/scb27cl.htm

[5] Laboratory Division, Norfolk Naval Shipyard, Portsmouth, VA, Laboratory Report No. 91NN00999, February 15, 1991.

[6] Laboratory Division, Quality Assurance Office, Puget Sound Naval Shipyard, Bremerton, WA, Laboratory Report No. 95PS00019 January 23, 1995; 95PS00028 January 21, 1995; 95PS00029 January 21, 1995; 95PS00032 January 21, 1995; 95PS00034 January 23, 1995; and 95PS00035 January 23, 1995.

[7] Analab Corporation P.O. Box 9000, Kilgore, TX 75663-9000, Laboratory Report No. 65539 February 10, 2004.

[8] Final Weight Report, Aircraft Carrier CV9 USS *Essex*, Office of Supervisor of Shipbuilding for US Navy, Newport News Shipbuilding and Dry Dock Company, Newport News, VA, 1945.

[9] Progress Report, *Oriskany* Project 50% Completion Conference, Supervisor of Shipbuilding for US Navy, Corpus Christi, TX, May 6, 2004.

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Appendix E

Empirical PCB Release for ex-ORISKANY over initial 2-year timeframe – Dataset Development for Time Dynamic Model .

The release of PCBs from ex-ORISKANY over the initial time period 0-730 days is determined by the quantity of PCB-containing bulk products onboard and the PCB-containing-material-specific release rates determined empirically in the laboratory (SSC-SD, 2004). This information was used to prepare a vessel-specific release dataset for use in modeling initial or "transient" releases over an initial 2-year period subsequent to the sinking event. After the transient release period, PRAM uses the empirically determined material-specific release rates to evaluate the fate and effects of PCBs at a point when the reef community is considered well established, i.e. at 2 years post-sinking. The material-specific and PCB homolog-specific rates corresponding to 2 years were computed from a regression analysis presented in the PRAM Documentation-Volume 1 (NEHC, 2005) and are also used here as the release from the empirical endpoints of each of the material-specific leaching studies out to t = 730 days. This provides a link between the empirical rates used in the time dynamic model and rates based on the data regressions that PRAM uses.

The empirical material-specific PCB release rates (SSC-SD, 2004) are plotted in Figure 1 on a total PCB (tPCBs) basis. The corresponding material-specific vessel releases calculated for ex-ORISKANY as initially prepared (CACI, 2004) are plotted in Figure 2. Note that because the empirical leach rate study evaluated each PCB-containing material separately, data were collected on slightly different time intervals. As a result, each shipboard solid leaching curve exhibits slightly different timeframes over which PCB release was quantified. This can be seen most clearly in Figure 2, where it is also demonstrated that the total release is dominated by the PCB release from bulkhead insulation (BHI). For this reason, the release data intervals for BHI were selected as the default time-intervals for the time dynamic model dataset. These time intervals are shown in Table 1.

The initial time domain model dataset was developed on a homolog basis for the selected time-intervals in Table 1. Separation by homolog was necessary because a) empirical leaching curves for each shipboard solid release differently for each homolog and, b) the PRAM evaluates PCBs on a homolog basis. To accurately prepare the time domain model dataset, the average release rates for each shipboard solid onboard the ex-ORISKANY were first summed on a daily basis to give a daily total release rate. This ensures that each release contribution from each shipboard solid is included in the total vessel release. Each daily total release rate for each homologue was then used to calculate an average daily release rate over each of the time-intervals in Table 1. Using this process, 2 distinct datasets were prepared, one dataset reflecting the initial vessel preparation scenario (CACI, 2004) (Table 2) and another dataset reflecting the final vessel preparation scenario(CACI, 2004b) (Table 3). These two vessel release datasets are shown in Tables 4 and 5 and were used in modeling the transient PCB releases under each vessel preparation scenario. These data are commensurate with those used in the PRAM analysis with respect to vessel preparation scenarios, allowing risk reduction evaluations to be performed. The vessel release behavior resembles a step-function as illustrated in Figures 3 and 4, plots of the daily homologue release using the datasets for each of these two vessel preparation scenarios.

Dr. Robert George, SSC-SD
15 December 2004

References.

SSC-SD 2004. SPAWAR Systems Center – San Diego, "Draft Final Report: Investigation of Polychlorinated Biphenyl (PCB) Release-Rates from Selected Shipboard Solid Materials Under Laboratory-Simulated Shallow Ocean (Artificial Reef) Environments", October 2004.

NEHC, 2005. Navy Environmental Health Center, "Prospective Risk Assessment Model", Volume I, 11 May 2005.

CACI 2004. CACI Incorporated, "Final Report Revision 1: Polychlorinated biphenyls (PCB) Source Term Estimates for ex-ORISKANY (CVA 34)", May 13, 2004.

CACI 2004b. CACI Incorporated, "Final Report Revision 4: Polychlorinated biphenyls (PCB) Source Term Estimates for ex-ORISKANY (CVA 34)", December 7, 2004.

Empirical PCB Release for ex-ORISKANY over initial 2-year timeframe - Dataset Development for Time Dynamic Model .

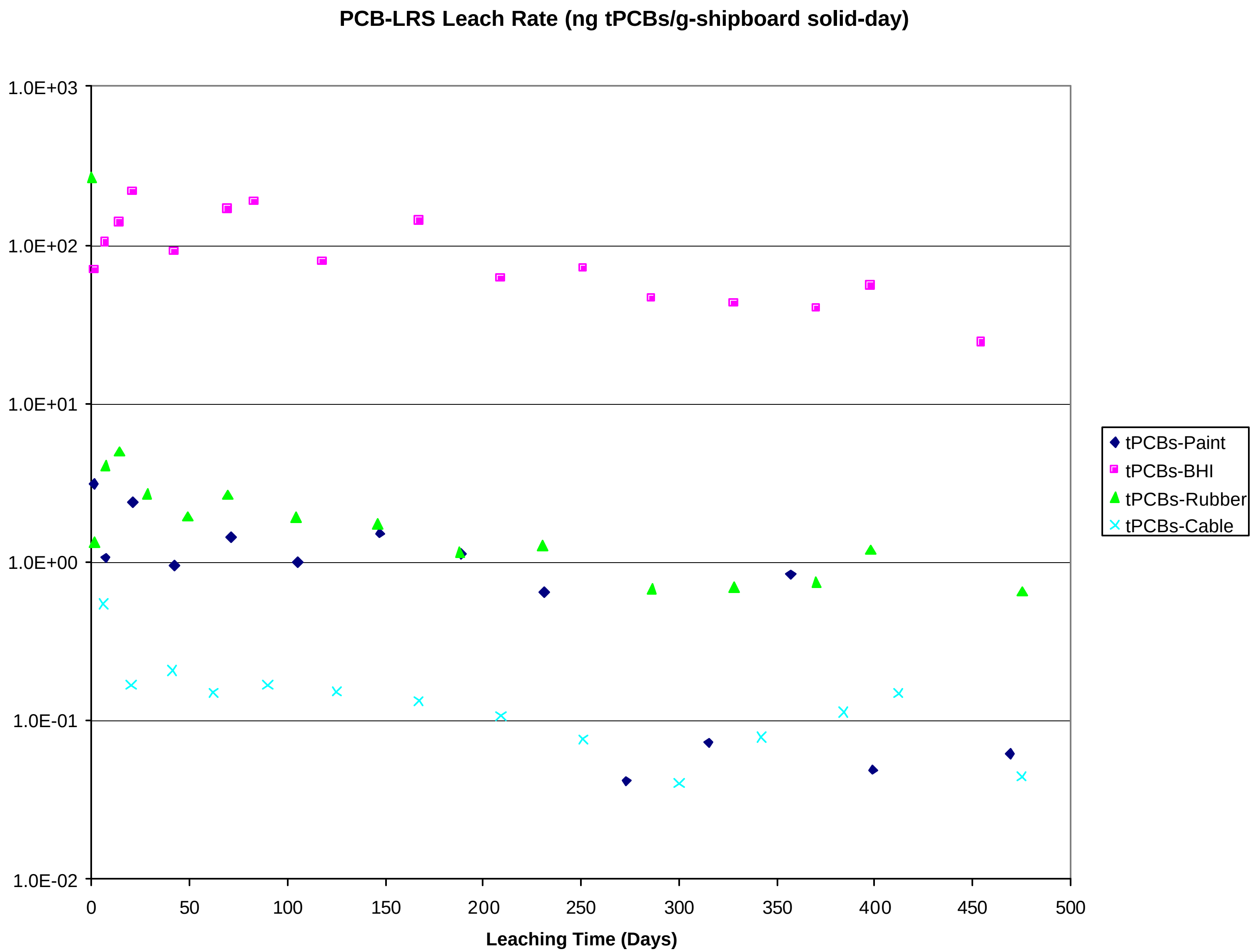


Figure 1. Empirical Leach Rate Study Results for only those shipboard solids onboard ex-ORISKANY. Each data point in this plot is indexed to the time interval endpoint and represents the average leach rate over that time interval. The empirical leach rates for rubber apply to both the rubber "products" and rubber "gaskets" onboard ex-ORISKANY.

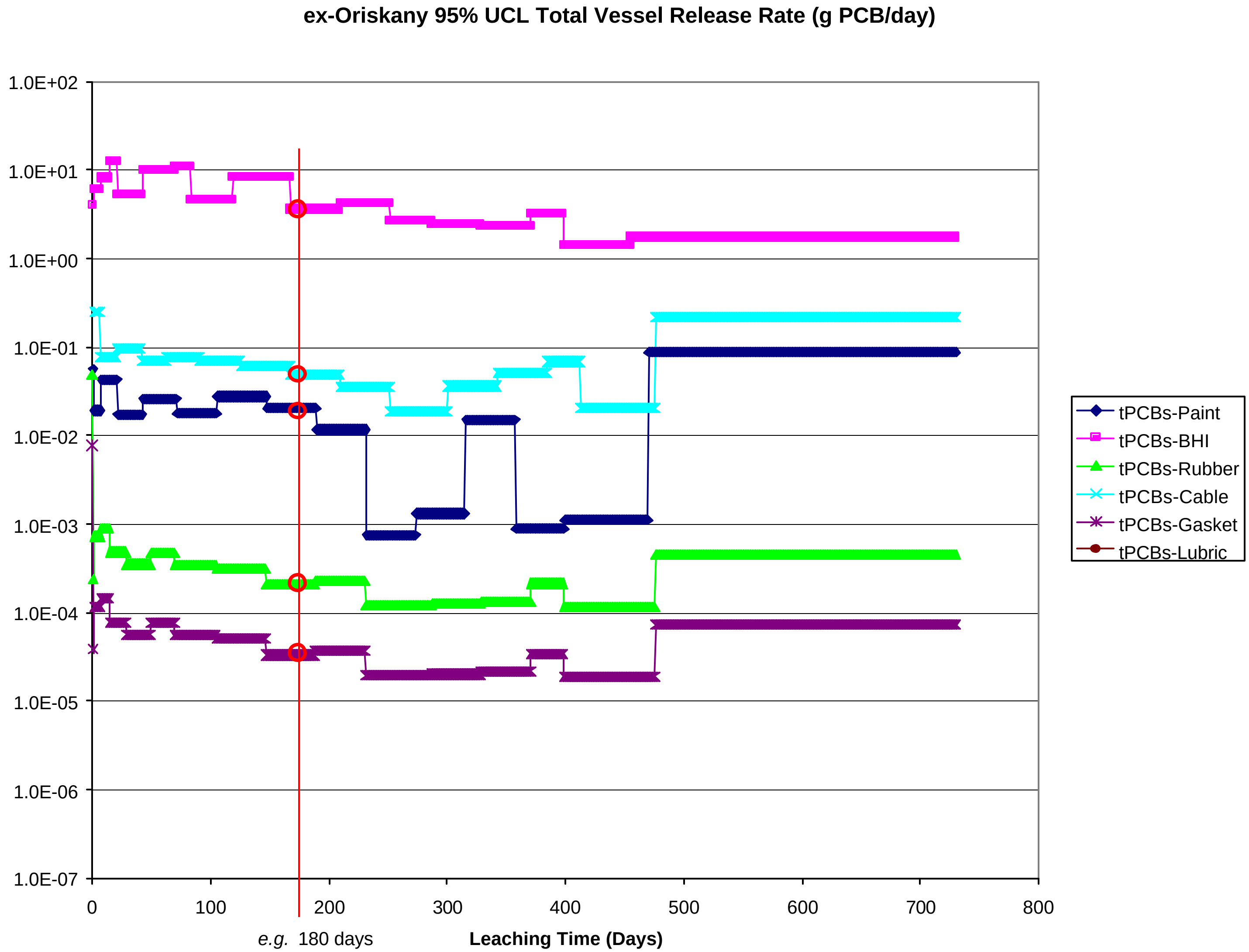


Figure 2. Ex-ORISKANY tPCBs Vessel Release by Shipboard Solid Type for initial preparation scenario (10% BHI removal). Note the slightly different time-intervals for each shipboard solid, a result of slight differences in data collection intervals for each material tested in the leach rate study. The total release on any given day X is the sum of release rates on day X for each material (*e.g.* 180-day vertical line above).

Table 1. Time Intervals for Bulkhead Insulation Corresponding to Empirical Leach Rate Study. In the leach rate study, empirical leach rates were determined between each leaching time, i.e. over each leaching interval.

Leaching Time (days)	Leaching Interval (days)
0	
0.007	0.007
1	1.163
7	5.906
14	7.007
21	7.015
42	21.129
69	27.074
83	13.838
118	34.997
167	48.969
209	42.026
251	42.061
286	34.958
328	41.942
370	42.024
398	27.963
454	56.240
730	275.681

Table 2. Ex-ORISKANY Initial Vessel Preparation Conditions (10% BHI removed). Reproduced from Reference [3].

Material	FWR Wt (lbs)	30yr Growth	Avg.PCB Conc. ppm	95% UCL	Lbs PCB	95% UCL lbs	Fraction Remaining	Material Remaining	lbs PCBs	95%UCL lbs
Paints	298999	3	11.6	19.7	10.4	17.7	0.95	852147.15	9.88	16.815
Bulkhead Insulation	115695	1	215.1	587.7	24.9	68	0.9	104125.5	22.41	61.2
Rubber Products	11898	1	37.3	50.9	0.4	0.6	1	11898	0.4	0.6
Cable Insulation	403600	1.3	1493.9	2766	783.8	1451.3	0.9	472212	705.42	1306.17
Vent. Gaskets	2680	1.2	20.3	33.5	0.1	0.1	1	3216	0.1	0.1
Lubricants	208140	1	60.3	106.8	12.6	22.2	0	0	0	0

Table 3. Ex-ORISKANY Final Vessel Preparation Conditions (72.6% BHI removed). Reproduced from Reference [4].

Material	FWR Wt (lbs)	30yr Growth	Avg.PCB Conc. ppm	95% UCL	Lbs PCB	95% UCL lbs	Fraction Remaining	Material Remaining	lbs PCBs	95%UCL lbs
Paints	298999	3	11.6	19.7	10.4	17.7	0.95	852147.15	9.88	16.815
Bulkhead Insulation	115695	1	215.1	587.7	24.9	68	0.273	31584.735	6.7977	18.564
Rubber Products	11898	1	37.3	50.9	0.4	0.6	1	11898	0.4	0.6
Cable Insulation	403600	1.3	1493.9	2766	783.8	1451.3	0.9	472212	705.42	1306.17
Vent. Gaskets	2680	1.2	20.3	33.5	0.1	0.1	1	3216	0.1	0.1
Lubricants	208140	1	60.3	106.8	12.6	22.2	0	0	0	0

Table 4. Ex-ORISKANY Total Vessel Release Rates (g PCB/day) for Initial Vessel Preparation Conditions (10% BHI removed). The total mass release (g PCB) is also included and is calculated by integrating each average daily release rate over its corresponding interval and summing the results (mass released per interval) across the entire 730 days.

Leaching Time (days)	Leaching Interval (days)	Cl1-all	Cl2-all	Cl3-all	Cl4-all	Cl5-all	Cl6-all	Cl7-all	Cl8-all	Cl9-all	Cl10-all	tPCBs-all
0												
0.007	0.007	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.5E-02	0.0E+00	0.0E+00	0.0E+00	5.5E-02
1	1.163	0.0E+00	0.0E+00	6.8E-02	1.6E+00	1.5E+00	0.0E+00	9.3E-01	0.0E+00	0.0E+00	0.0E+00	4.1E+00
7	5.906	6.1E-05	2.8E-01	2.1E-01	2.7E+00	2.5E+00	4.0E-01	1.7E-01	0.0E+00	0.0E+00	0.0E+00	6.2E+00
14	7.007	0.0E+00	2.1E-01	1.8E-01	3.5E+00	3.8E+00	4.3E-01	1.1E-01	0.0E+00	0.0E+00	0.0E+00	8.2E+00
21	7.015	3.9E-05	1.1E-02	1.7E-01	4.0E+00	7.3E+00	1.1E+00	1.6E-02	0.0E+00	0.0E+00	0.0E+00	1.3E+01
42	21.129	3.4E-05	9.3E-03	8.4E-02	1.9E+00	2.9E+00	4.5E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.3E+00
69	27.074	8.0E-06	6.1E-03	7.3E-02	2.5E+00	5.9E+00	1.4E+00	5.8E-04	0.0E+00	0.0E+00	0.0E+00	9.8E+00
83	13.838	2.7E-05	1.0E-02	8.9E-02	2.7E+00	6.8E+00	1.2E+00	1.1E-01	0.0E+00	0.0E+00	0.0E+00	1.1E+01
118	34.997	2.5E-05	4.4E-03	5.4E-02	1.4E+00	2.7E+00	5.5E-01	4.5E-04	0.0E+00	9.1E-04	5.1E-04	4.7E+00
167	48.969	2.1E-05	1.6E-03	3.8E-02	1.8E+00	5.0E+00	1.3E+00	9.4E-02	0.0E+00	1.6E-04	9.1E-05	8.3E+00
209	42.026	1.8E-05	1.3E-03	3.4E-02	1.0E+00	2.1E+00	4.7E-01	4.7E-02	0.0E+00	0.0E+00	0.0E+00	3.6E+00
251	42.061	1.9E-05	2.2E-06	3.9E-02	1.2E+00	2.4E+00	4.8E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E+00
286	34.958	2.1E-05	2.5E-06	2.9E-02	1.0E+00	1.4E+00	2.3E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.7E+00
328	41.942	1.9E-05	1.2E-05	2.9E-02	6.9E-01	1.4E+00	3.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.5E+00
370	42.024	1.9E-05	1.7E-05	3.2E-02	8.2E-01	1.2E+00	2.5E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E+00
398	27.963	1.7E-05	3.8E-05	6.3E-02	9.8E-01	1.7E+00	4.8E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+00
454	56.240	1.5E-05	1.1E-05	3.5E-02	4.4E-01	7.3E-01	2.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E+00
730	275.681	1.4E-05	1.4E-01	2.7E-02	5.4E-01	9.9E-01	2.0E-01	9.6E-02	0.0E+00	1.1E-03	5.9E-04	2.0E+00
	Total Release (g PCB)	1.3E-02	4.3E+01	3.0E+01	7.4E+02	1.5E+03	3.1E+02	3.8E+01	0.0E+00	3.3E-01	1.9E-01	2.6E+03

Table 5. Ex-ORISKANY Total Vessel Release Rates (g PCB/day) for Final Vessel Preparation Conditions (72.6% BHI removed). The total mass release (g PCB) is also included and is calculated by integrating each average daily release rate over its corresponding interval and summing the results (mass released per interval) across the entire 730 days.

Leaching Time (days)	Leaching Interval (days)	Cl1-all	Cl2-all	Cl3-all	Cl4-all	Cl5-all	Cl6-all	Cl7-all	Cl8-all	Cl9-all	Cl10-all	tPCBs-all
0												
0.007	0.007	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.5E-02	0.0E+00	0.0E+00	0.0E+00	5.5E-02
1	1.163	0.0E+00	0.0E+00	2.0E-02	4.8E-01	4.5E-01	0.0E+00	3.2E-01	0.0E+00	0.0E+00	0.0E+00	1.3E+00
7	5.906	6.1E-05	1.7E-01	6.4E-02	8.3E-01	7.9E-01	1.2E-01	6.7E-02	0.0E+00	0.0E+00	0.0E+00	2.1E+00
14	7.007	0.0E+00	6.4E-02	5.6E-02	1.1E+00	1.2E+00	1.4E-01	4.6E-02	0.0E+00	0.0E+00	0.0E+00	2.6E+00
21	7.015	3.9E-05	3.8E-03	5.2E-02	1.3E+00	2.3E+00	3.4E-01	1.6E-02	0.0E+00	0.0E+00	0.0E+00	3.9E+00
42	21.129	3.4E-05	5.8E-03	2.6E-02	6.0E-01	9.2E-01	1.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E+00
69	27.074	8.0E-06	3.7E-03	2.2E-02	7.8E-01	1.8E+00	4.2E-01	5.8E-04	0.0E+00	0.0E+00	0.0E+00	3.0E+00
83	13.838	2.7E-05	1.0E-02	2.7E-02	8.4E-01	2.1E+00	3.8E-01	3.6E-02	0.0E+00	0.0E+00	0.0E+00	3.4E+00
118	34.997	2.5E-05	2.8E-03	1.7E-02	4.3E-01	8.4E-01	1.9E-01	4.5E-04	0.0E+00	9.1E-04	5.1E-04	1.5E+00
167	48.969	2.1E-05	5.1E-04	1.2E-02	5.7E-01	1.6E+00	4.1E-01	2.8E-02	0.0E+00	1.6E-04	9.1E-05	2.6E+00
209	42.026	1.8E-05	4.0E-04	1.0E-02	3.2E-01	6.5E-01	1.4E-01	1.4E-02	0.0E+00	0.0E+00	0.0E+00	1.1E+00
251	42.061	1.9E-05	2.2E-06	1.2E-02	3.7E-01	7.6E-01	1.5E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E+00
286	34.958	2.1E-05	2.5E-06	8.9E-03	3.1E-01	4.4E-01	6.9E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.3E-01
328	41.942	1.9E-05	1.2E-05	8.9E-03	2.2E-01	4.5E-01	1.1E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E-01
370	42.024	1.9E-05	1.7E-05	9.6E-03	2.6E-01	4.0E-01	8.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.5E-01
398	27.963	1.7E-05	3.8E-05	1.9E-02	3.1E-01	5.5E-01	1.5E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
454	56.240	1.5E-05	1.1E-05	1.1E-02	1.4E-01	2.4E-01	7.2E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.6E-01
730	275.681	1.4E-05	1.4E-01	1.0E-02	1.7E-01	3.2E-01	7.9E-02	7.3E-02	0.0E+00	1.1E-03	5.9E-04	8.0E-01
	Total Release (g PCB)	1.3E-02	4.1E+01	9.7E+00	2.3E+02	4.6E+02	1.0E+02	2.4E+01	0.0E+00	3.3E-01	1.9E-01	8.7E+02

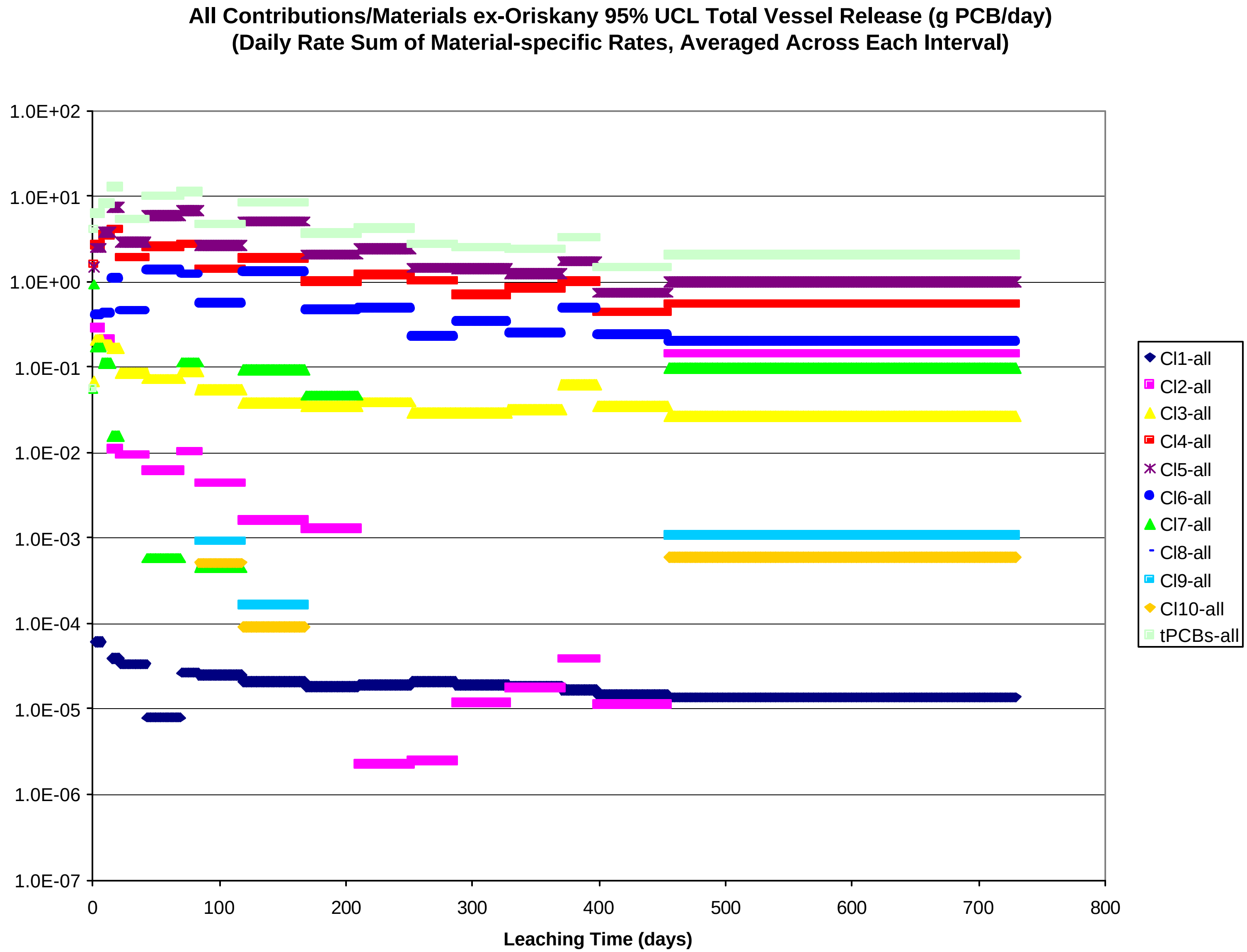


Figure 3. Homolog and tPCBs Plots of Ex-ORISKANY Total Vessel Release Rates (g PCB/day) for Initial Vessel Preparation Scenario (10% BHI removed).

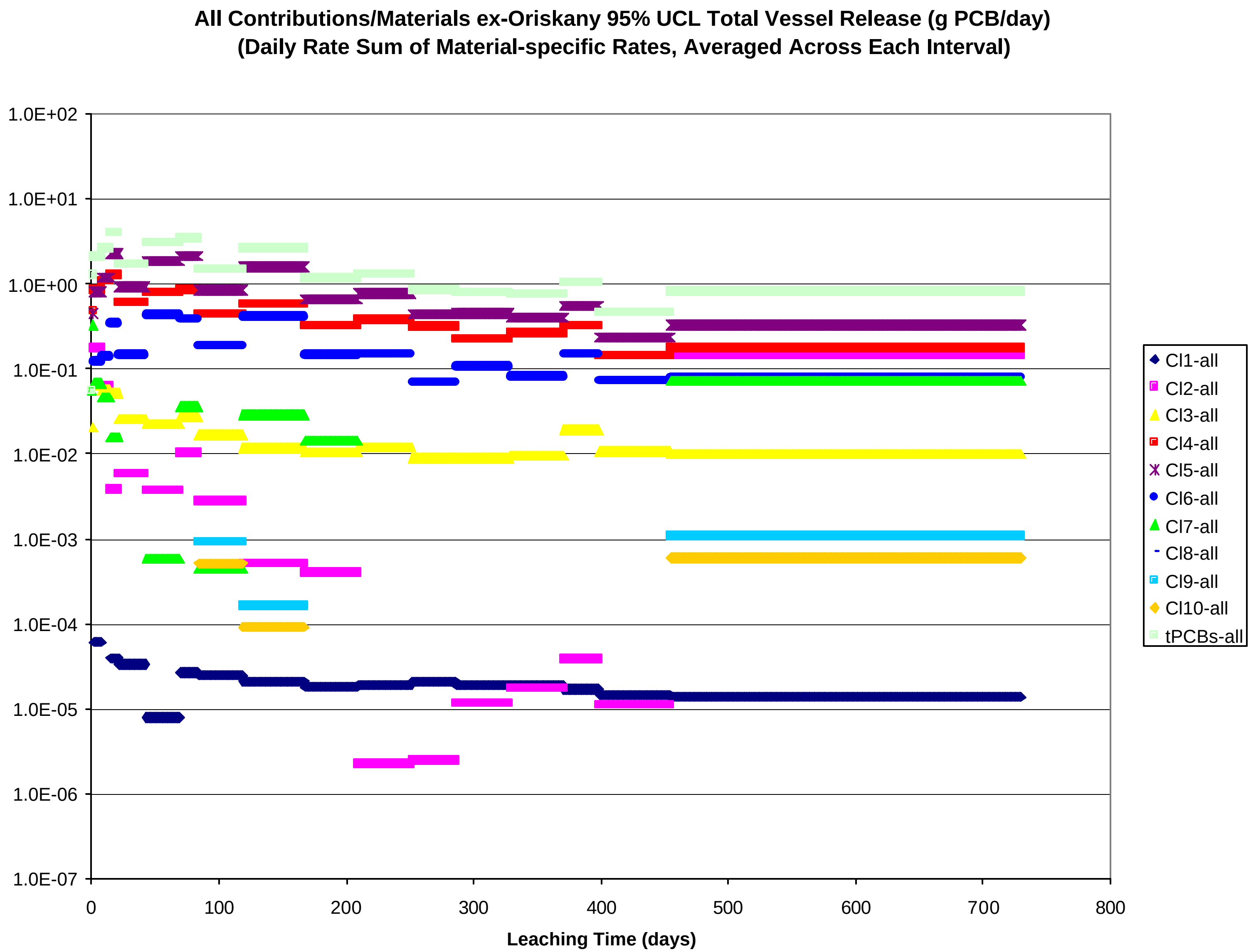


Figure 4. Homolog and tPCBs Plots of Ex-ORISKANY Total Vessel Release Rates (g PCB/day) for Final Vessel Preparation Scenario (72.6% BHI removed).

FIGURE F 1 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 day
Scenario run on	5/10/2005	13:55	Distance Interval	15 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	3.1637E-16	2.8766E-12	1.0036E-12	1.4739E-11	1.1981E-11	1.6642E-13	5.0989E-13	0	0	0	3.12765E-11
Zooplankton (TL-II)	copepods	2.8745E-10	3.7622E-06	1.6956E-06	2.6866E-05	1.4967E-05	9.6027E-07	1.1886E-06	0	0	0	4.944E-05
Planktivore (TL-III)	herring	8.6385E-11	4.2389E-06	3.4527E-06	0.00010602	0.00010613	7.5033E-06	9.058E-06	0	0	0	0.000236408
Piscivore (TL-IV)	jack	2.258E-11	7.4691E-07	9.1655E-07	6.1927E-05	0.00018604	2.2532E-05	3.066E-05	0	0	0	0.000302821
Reef / Vessel Community												
Attached Algae	Algae	3.968E-11	3.7656E-07	1.4237E-07	1.9864E-06	1.7578E-06	7.811E-08	6.918E-08	0	0	0	4.41045E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	6.9769E-10	8.2952E-06	3.6607E-06	5.7788E-05	3.1433E-05	1.2575E-06	1.2665E-06	0	0	0	0.000103701
Invertibrate Omnivore (TL-II)	urchin	2.1263E-08	0.00058093	0.0003831	0.01033459	0.00935877	0.00030115	0.00021999	0	0	0	0.021178532
Invertibrate Forager (TL-III)	crab	7.256E-08	0.00083848	0.00046147	0.00912798	0.00766003	0.00032105	0.00029257	0	0	0	0.018701646
Vertibrate Forager (TL-III)	triggerfish	1.8431E-08	0.00027562	0.00018354	0.00505548	0.00813505	0.00045401	0.0004252	0	0	0	0.014528923
Predator (TL-IV)	grouper	1.0536E-08	0.00016731	0.00011821	0.00376267	0.00830296	0.00058118	0.0005801	0	0	0	0.013512442
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.8788E-10	2.6012E-06	1.2074E-06	2.0051E-05	1.1295E-05	4.4274E-07	4.6401E-07	0	0	0	3.60617E-05
Epifaunal invert. (TL-II)	nematode	2.6217E-10	5.4419E-06	2.8991E-06	5.5085E-05	3.4073E-05	1.4199E-06	1.4898E-06	0	0	0	0.000100408
Forager (TL-III)	lobster	3.3942E-10	6.6078E-06	4.5131E-06	0.00011449	9.5797E-05	3.9321E-06	3.7957E-06	0	0	0	0.000229136
Predator (TL-IV)	flounder	6.9243E-11	4.0595E-06	4.7798E-06	0.00024852	0.00042047	2.2218E-05	2.2228E-05	0	0	0	0.000722275

FIGURE F 2 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 day
Scenario run on	5/10/2005	13:59	Distance Interval	45 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	5.1761E-16	4.706E-12	1.6416E-12	2.4111E-11	1.9596E-11	2.7188E-13	8.3344E-13	0	0	0	5.11607E-11
Zooplankton (TL-II)	copepods	2.4774E-10	3.2421E-06	1.4609E-06	2.3151E-05	1.2895E-05	8.2593E-07	1.0238E-06	0	0	0	4.25981E-05
Planktivore (TL-III)	herring	7.4453E-11	3.6529E-06	2.9748E-06	9.1359E-05	9.1437E-05	6.4536E-06	7.8025E-06	0	0	0	0.00020368
Piscivore (TL-IV)	jack	1.9461E-11	6.4366E-07	7.8969E-07	5.3363E-05	0.00016028	1.9379E-05	2.6411E-05	0	0	0	0.000260864
Reef / Vessel Community												
Attached Algae	Algae	3.4198E-11	3.245E-07	1.2267E-07	1.7117E-06	1.5144E-06	6.7181E-08	5.9588E-08	0	0	0	3.8E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	6.0131E-10	7.1484E-06	3.154E-06	4.9795E-05	2.708E-05	1.0816E-06	1.0909E-06	0	0	0	8.93507E-05
Invertibrate Omnivore (TL-II)	urchin	2.1244E-08	0.00058014	0.0003825	0.01031622	0.00933798	0.00030019	0.00021911	0	0	0	0.021136152
Invertibrate Forager (TL-III)	crab	7.2527E-08	0.00083778	0.00046097	0.00911486	0.00764852	0.0003205	0.000292	0	0	0	0.018674696
Vertibrate Forager (TL-III)	triggerfish	1.8421E-08	0.00027506	0.0001829	0.0050224	0.00807999	0.00045066	0.00042161	0	0	0	0.014432638
Predator (TL-IV)	grouper	1.0528E-08	0.00016699	0.00011784	0.0037413	0.00825347	0.0005776	0.00057617	0	0	0	0.013433381
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.6193E-10	2.2416E-06	1.0403E-06	1.7278E-05	9.7309E-06	3.808E-07	3.9966E-07	0	0	0	3.10714E-05
Epifaunal invert. (TL-II)	nematode	2.2595E-10	4.6896E-06	2.4978E-06	4.7466E-05	2.9354E-05	1.2212E-06	1.2832E-06	0	0	0	8.65128E-05
Forager (TL-III)	lobster	2.9253E-10	5.6943E-06	3.8884E-06	9.8656E-05	8.253E-05	3.3819E-06	3.2694E-06	0	0	0	0.00019742
Predator (TL-IV)	flounder	5.9677E-11	3.4983E-06	4.1182E-06	0.00021415	0.00036224	1.9109E-05	1.9146E-05	0	0	0	0.000622262

FIGURE F 3 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 day
Scenario run on	5/12/2005	14:08	Distance Interval	60 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	5.9428E-16	5.4028E-12	1.8845E-12	2.768E-11	2.2496E-11	3.1193E-13	9.5645E-13	0	0	0	5.87324E-11
Zooplankton (TL-II)	copepods	2.3261E-10	3.0439E-06	1.3715E-06	2.1735E-05	1.2105E-05	7.7474E-07	9.6107E-07	0	0	0	3.9991E-05
Planktivore (TL-III)	herring	6.9906E-11	3.4296E-06	2.7927E-06	8.5772E-05	8.5837E-05	6.0536E-06	7.3241E-06	0	0	0	0.000191209
Piscivore (TL-IV)	jack	1.8272E-11	6.0432E-07	7.4135E-07	5.0099E-05	0.00015046	1.8178E-05	2.4792E-05	0	0	0	0.000244876
Reef / Vessel Community												
Attached Algae	Algae	3.2109E-11	3.0466E-07	1.1516E-07	1.607E-06	1.4216E-06	6.3017E-08	5.5933E-08	0	0	0	3.56739E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	5.6458E-10	6.7114E-06	2.9609E-06	4.675E-05	2.5421E-05	1.0146E-06	1.024E-06	0	0	0	8.38827E-05
Invertibrate Omnivore (TL-II)	urchin	2.1237E-08	0.00057984	0.00038228	0.01030922	0.00933006	0.00029982	0.00021877	0	0	0	0.021120004
Invertibrate Forager (TL-III)	crab	7.2515E-08	0.00083751	0.00046078	0.00910986	0.00764414	0.00032029	0.00029178	0	0	0	0.018664428
Vertibrate Forager (TL-III)	triggerfish	1.8418E-08	0.00027485	0.00018265	0.0050098	0.00805901	0.00044938	0.00042024	0	0	0	0.014395949
Predator (TL-IV)	grouper	1.0525E-08	0.00016687	0.0001177	0.00373315	0.00823462	0.00057624	0.00057467	0	0	0	0.013403255
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.5204E-10	2.1045E-06	9.7659E-07	1.6221E-05	9.1349E-06	3.572E-07	3.7514E-07	0	0	0	2.91699E-05
Epifaunal invert. (TL-II)	nematode	2.1215E-10	4.4029E-06	2.3449E-06	4.4564E-05	2.7556E-05	1.1455E-06	1.2045E-06	0	0	0	8.12179E-05
Forager (TL-III)	lobster	2.7466E-10	5.3461E-06	3.6504E-06	9.2622E-05	7.7475E-05	3.1723E-06	3.0688E-06	0	0	0	0.000185335
Predator (TL-IV)	flounder	5.6032E-11	3.2844E-06	3.8661E-06	0.00020105	0.00034005	1.7925E-05	1.7971E-05	0	0	0	0.000584153

FIGURE F 4 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier	N/A	Time Interval	1 week
Scenario run on	5/10/2005 13:59	Distance Interval	15 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	3.7114E-16	3.7554E-12	1.3782E-12	1.873E-11	1.6719E-11	6.8108E-13	3.8487E-13	0	0	0	4.16492E-11
Zooplankton (TL-II)	copepods	3.2627E-10	4.5273E-06	1.9988E-06	3.1211E-05	1.7886E-05	1.2948E-06	5.8831E-07	0	0	0	5.75065E-05
Planktivore (TL-III)	herring	9.8049E-11	5.101E-06	4.0702E-06	0.00012317	0.00012683	1.0115E-05	4.4851E-06	0	0	0	0.00027377
Piscivore (TL-IV)	jack	2.5628E-11	8.9881E-07	1.0804E-06	7.1943E-05	0.00022232	3.0372E-05	1.5185E-05	0	0	0	0.000341794
Reef / Vessel Community												
Attached Algae	Algae	4.5038E-11	4.5314E-07	1.6783E-07	2.3077E-06	2.1005E-06	1.0515E-07	3.44E-08	0	0	0	5.16875E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	7.9189E-10	9.9823E-06	4.3153E-06	6.7134E-05	3.7561E-05	1.6945E-06	6.2768E-07	0	0	0	0.000121316
Invertibrate Omnivore (TL-II)	urchin	2.4132E-08	0.00069892	0.0004514	0.01200281	0.01117852	0.00040472	0.00010929	0	0	0	0.024845691
Invertibrate Forager (TL-III)	crab	8.2483E-08	0.00103531	0.00057239	0.01185379	0.01078359	0.00049481	0.00016196	0	0	0	0.024901928
Vertibrate Forager (TL-III)	triggerfish	2.0918E-08	0.0003316	0.00021627	0.00587162	0.00971715	0.00061059	0.0002115	0	0	0	0.016958752
Predator (TL-IV)	grouper	1.1958E-08	0.00020129	0.00013929	0.00437009	0.00991768	0.00078154	0.00028852	0	0	0	0.015698419
Benthic Community												
Infaunal invert. (TL-II)	polychaete	2.1326E-10	3.1305E-06	1.4236E-06	2.3298E-05	1.3507E-05	6.1466E-07	2.4435E-07	0	0	0	4.22179E-05
Epifaunal invert. (TL-II)	nematode	2.9757E-10	6.5491E-06	3.4181E-06	6.4001E-05	4.0737E-05	1.9538E-06	7.7021E-07	0	0	0	0.00011743
Forager (TL-III)	lobster	3.8525E-10	7.9519E-06	5.3207E-06	0.00013302	0.00011452	5.3901E-06	1.9553E-06	0	0	0	0.000268157
Predator (TL-IV)	flounder	7.8593E-11	4.8853E-06	5.6353E-06	0.00028874	0.00050265	3.045E-05	1.1444E-05	0	0	0	0.000843806

FIGURE F 5 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 week
Scenario run on	5/10/2005	14:00	Distance Interval	45 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	6.0728E-16	6.1447E-12	2.255E-12	3.0647E-11	2.7354E-11	1.1138E-12	6.297E-13	0	0	0	6.81447E-11
Zooplankton (TL-II)	copepods	2.8122E-10	3.9023E-06	1.7229E-06	2.6902E-05	1.5415E-05	1.1154E-06	5.0721E-07	0	0	0	4.95647E-05
Planktivore (TL-III)	herring	8.4514E-11	4.3968E-06	3.5082E-06	0.00010616	0.00010931	8.7139E-06	3.8668E-06	0	0	0	0.000235958
Piscivore (TL-IV)	jack	2.2091E-11	7.7473E-07	9.3128E-07	6.2009E-05	0.00019161	2.6164E-05	1.3092E-05	0	0	0	0.000294579
Reef / Vessel Community												
Attached Algae	Algae	3.882E-11	3.9058E-07	1.4466E-07	1.989E-06	1.8104E-06	9.0581E-08	2.9655E-08	0	0	0	4.45485E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	6.8256E-10	8.6041E-06	3.7194E-06	5.7863E-05	3.2373E-05	1.4597E-06	5.4114E-07	0	0	0	0.000104561
Invertibrate Omnivore (TL-II)	urchin	2.411E-08	0.00069797	0.00045071	0.0119815	0.01115375	0.00040345	0.00010885	0	0	0	0.024796244
Invertibrate Forager (TL-III)	crab	8.2445E-08	0.00103443	0.00057177	0.01183667	0.01076661	0.00049388	0.00016162	0	0	0	0.024865059
Vertibrate Forager (TL-III)	triggerfish	2.0907E-08	0.00033093	0.00021551	0.00583325	0.0096515	0.00060606	0.00020969	0	0	0	0.016846963
Predator (TL-IV)	grouper	1.1948E-08	0.00020091	0.00013885	0.0043453	0.00985867	0.0007767	0.00028653	0	0	0	0.015606981
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.8381E-10	2.6982E-06	1.2271E-06	2.0081E-05	1.1641E-05	5.2949E-07	2.1062E-07	0	0	0	3.63872E-05
Epifaunal invert. (TL-II)	nematode	2.5649E-10	5.6449E-06	2.9461E-06	5.5163E-05	3.511E-05	1.6831E-06	6.6393E-07	0	0	0	0.000101211
Forager (TL-III)	lobster	3.3206E-10	6.854E-06	4.5861E-06	0.00011465	9.8701E-05	4.6432E-06	1.6855E-06	0	0	0	0.00023112
Predator (TL-IV)	flounder	6.7742E-11	4.2108E-06	4.8572E-06	0.00024887	0.00043321	2.6231E-05	9.8646E-06	0	0	0	0.000727248

FIGURE F 6 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 week
Scenario run on	5/12/2005	14:10	Distance Interval	60 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	6.9726E-16	7.0551E-12	2.5891E-12	3.5187E-11	3.1406E-11	1.2785E-12	7.2297E-13	0	0	0	7.82394E-11
Zooplankton (TL-II)	copepods	2.6406E-10	3.6641E-06	1.6177E-06	2.5259E-05	1.4474E-05	1.047E-06	4.7631E-07	0	0	0	4.65385E-05
Planktivore (TL-III)	herring	7.9356E-11	4.1284E-06	3.2941E-06	9.9681E-05	0.00010264	8.1798E-06	3.6312E-06	0	0	0	0.00022155
Piscivore (TL-IV)	jack	2.0743E-11	7.2745E-07	8.7444E-07	5.8223E-05	0.00017991	2.4561E-05	1.2294E-05	0	0	0	0.000276587
Reef / Vessel Community												
Attached Algae	Algae	3.645E-11	3.6674E-07	1.3583E-07	1.8676E-06	1.6998E-06	8.5029E-08	2.7847E-08	0	0	0	4.18282E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	6.409E-10	8.0789E-06	3.4924E-06	5.4331E-05	3.0396E-05	1.3702E-06	5.0816E-07	0	0	0	9.81769E-05
Invertibrate Omnivore (TL-II)	urchin	2.4102E-08	0.00069761	0.00045044	0.01197338	0.01114431	0.00040296	0.00010869	0	0	0	0.024777403
Invertibrate Forager (TL-III)	crab	8.2431E-08	0.00103409	0.00057153	0.01183015	0.01076014	0.00049353	0.00016148	0	0	0	0.024851011
Vertibrate Forager (TL-III)	triggerfish	2.0902E-08	0.00033067	0.00021522	0.00581862	0.00962649	0.00060434	0.000209	0	0	0	0.016804367
Predator (TL-IV)	grouper	1.1945E-08	0.00020076	0.00013869	0.00433585	0.00983619	0.00077486	0.00028577	0	0	0	0.015572138
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.726E-10	2.5336E-06	1.1522E-06	1.8855E-05	1.093E-05	4.9704E-07	1.9777E-07	0	0	0	3.41655E-05
Epifaunal invert. (TL-II)	nematode	2.4084E-10	5.3003E-06	2.7663E-06	5.1796E-05	3.2966E-05	1.5799E-06	6.2343E-07	0	0	0	9.50315E-05
Forager (TL-III)	lobster	3.1179E-10	6.4357E-06	4.3062E-06	0.00010765	9.2673E-05	4.3586E-06	1.5826E-06	0	0	0	0.000217007
Predator (TL-IV)	flounder	6.3607E-11	3.9538E-06	4.5607E-06	0.00023368	0.00040676	2.4623E-05	9.2628E-06	0	0	0	0.000682834

FIGURE F 7 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	2 weeks
Scenario run on	5/10/2005	14:00	Distance Interval	15 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	3.3297E-17	1.5561E-12	1.2692E-12	2.3858E-11	2.5636E-11	9.6181E-13	2.5777E-13	0	0	0	5.35389E-11
Zooplankton (TL-II)	copepods	2.9645E-11	1.6053E-06	1.779E-06	3.9516E-05	2.7631E-05	1.6843E-06	3.8713E-07	0	0	0	7.2603E-05
Planktivore (TL-III)	herring	8.9088E-12	1.8087E-06	3.6225E-06	0.00015594	0.00019593	1.3159E-05	2.9513E-06	0	0	0	0.000373418
Piscivore (TL-IV)	jack	2.3286E-12	3.187E-07	9.6163E-07	9.1086E-05	0.00034345	3.9511E-05	9.9921E-06	0	0	0	0.000485316
Reef / Vessel Community												
Attached Algae	Algae	4.0922E-12	1.6067E-07	1.4938E-07	2.9217E-06	3.245E-06	1.3681E-07	2.2634E-08	0	0	0	6.63623E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	7.1952E-11	3.5395E-06	3.8407E-06	8.4998E-05	5.8027E-05	2.2044E-06	4.1302E-07	0	0	0	0.000153023
Invertibrate Omnivore (TL-II)	urchin	2.1927E-09	0.00024781	0.00040175	0.01519637	0.01726974	0.00052647	7.1902E-05	0	0	0	0.033714051
Invertibrate Forager (TL-III)	crab	7.5069E-09	0.00037653	0.00053503	0.01659825	0.01918987	0.00072599	0.00011768	0	0	0	0.037543352
Vertibrate Forager (TL-III)	triggerfish	1.9007E-09	0.00011757	0.00019249	0.00743388	0.01501204	0.00079432	0.00013929	0	0	0	0.023689593
Predator (TL-IV)	grouper	1.0866E-09	7.1372E-05	0.00012397	0.00553283	0.01532183	0.0010167	0.00019	0	0	0	0.022256708
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.9389E-11	1.1104E-06	1.2672E-06	2.9497E-05	2.0865E-05	8.0266E-07	1.677E-07	0	0	0	5.37109E-05
Epifaunal invert. (TL-II)	nematode	2.705E-11	2.3227E-06	3.0424E-06	8.1032E-05	6.2932E-05	2.5485E-06	5.2216E-07	0	0	0	0.000152399
Forager (TL-III)	lobster	3.5006E-11	2.82E-06	4.7358E-06	0.00016842	0.00017691	7.028E-06	1.3215E-06	0	0	0	0.000361235
Predator (TL-IV)	flounder	7.1416E-12	1.7325E-06	5.0158E-06	0.00036558	0.00077651	3.9702E-05	7.7314E-06	0	0	0	0.001196268

FIGURE F 8 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	2 weeks
Scenario run on	5/10/2005	14:01	Distance Interval	45 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	5.448E-17	2.5462E-12	2.0767E-12	3.9037E-11	4.1944E-11	1.5735E-12	4.2184E-13	0	0	0	8.75991E-11
Zooplankton (TL-II)	copepods	2.5551E-11	1.3837E-06	1.5334E-06	3.406E-05	2.3814E-05	1.4512E-06	3.3378E-07	0	0	0	6.25764E-05
Planktivore (TL-III)	herring	7.6787E-12	1.559E-06	3.1224E-06	0.00013441	0.00016887	1.1338E-05	2.5446E-06	0	0	0	0.000321844
Piscivore (TL-IV)	jack	2.0071E-12	2.7471E-07	8.2887E-07	7.851E-05	0.000296	3.4044E-05	8.6151E-06	0	0	0	0.000418275
Reef / Vessel Community												
Attached Algae	Algae	3.527E-12	1.3849E-07	1.2875E-07	2.5183E-06	2.7967E-06	1.1788E-07	1.9513E-08	0	0	0	5.71962E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	6.2016E-11	3.0509E-06	3.3104E-06	7.3261E-05	5.0011E-05	1.8994E-06	3.561E-07	0	0	0	0.000131889
Invertibrate Omnivore (TL-II)	urchin	2.1908E-09	0.00024748	0.00040113	0.01516939	0.01723146	0.00052481	7.1615E-05	0	0	0	0.033645888
Invertibrate Forager (TL-III)	crab	7.5034E-09	0.0003762	0.00053442	0.0165735	0.0191578	0.00072452	0.0001174	0	0	0	0.037483853
Vertibrate Forager (TL-III)	triggerfish	1.8997E-09	0.00011734	0.00019181	0.0073853	0.01491061	0.00078843	0.00013808	0	0	0	0.023531567
Predator (TL-IV)	grouper	1.0857E-09	7.1236E-05	0.00012358	0.00550145	0.01523067	0.00101042	0.00018867	0	0	0	0.022126013
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.6712E-11	9.5711E-07	1.0922E-06	2.5425E-05	1.7983E-05	6.9159E-07	1.4455E-07	0	0	0	4.62929E-05
Epifaunal invert. (TL-II)	nematode	2.3314E-11	2.0021E-06	2.6224E-06	6.9843E-05	5.4238E-05	2.1959E-06	4.5012E-07	0	0	0	0.000131351
Forager (TL-III)	lobster	3.0172E-11	2.4307E-06	4.082E-06	0.00014516	0.00015247	6.0554E-06	1.1392E-06	0	0	0	0.000311342
Predator (TL-IV)	flounder	6.1554E-12	1.4933E-06	4.3233E-06	0.0003151	0.00066923	3.4208E-05	6.6646E-06	0	0	0	0.00103102

FIGURE F 9 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	2 weeks
Scenario run on	5/12/2005	14:11	Distance Interval	60 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	6.2551E-17	2.9235E-12	2.3844E-12	4.482E-11	4.8157E-11	1.8065E-12	4.8439E-13	0	0	0	1.00576E-10
Zooplankton (TL-II)	copepods	2.3991E-11	1.2993E-06	1.4398E-06	3.1981E-05	2.2359E-05	1.3624E-06	3.1346E-07	0	0	0	5.87558E-05
Planktivore (TL-III)	herring	7.2099E-12	1.4639E-06	2.9319E-06	0.00012621	0.00015855	1.0644E-05	2.3896E-06	0	0	0	0.000302191
Piscivore (TL-IV)	jack	1.8846E-12	2.5795E-07	7.7829E-07	7.3718E-05	0.00027792	3.1961E-05	8.0904E-06	0	0	0	0.000392729
Reef / Vessel Community												
Attached Algae	Algae	3.3117E-12	1.3004E-07	1.2089E-07	2.3646E-06	2.6259E-06	1.1066E-07	1.8324E-08	0	0	0	5.37035E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	5.8229E-11	2.8647E-06	3.1084E-06	6.8789E-05	4.6956E-05	1.7832E-06	3.3441E-07	0	0	0	0.000123836
Invertibrate Omnivore (TL-II)	urchin	2.19E-09	0.00024735	0.0004009	0.01515911	0.01721688	0.00052418	7.1506E-05	0	0	0	0.033619915
Invertibrate Forager (TL-III)	crab	7.5021E-09	0.00037607	0.0005342	0.01656406	0.01914559	0.00072396	0.0001173	0	0	0	0.037461181
Vertibrate Forager (TL-III)	triggerfish	1.8993E-09	0.00011725	0.00019155	0.00736678	0.01487196	0.00078619	0.00013762	0	0	0	0.023471352
Predator (TL-IV)	grouper	1.0853E-09	7.1184E-05	0.00012343	0.00548949	0.01519593	0.00100802	0.00018816	0	0	0	0.022076213
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.5691E-11	8.987E-07	1.0256E-06	2.3873E-05	1.6884E-05	6.4927E-07	1.3573E-07	0	0	0	4.34664E-05
Epifaunal invert. (TL-II)	nematode	2.1891E-11	1.8799E-06	2.4623E-06	6.558E-05	5.0925E-05	2.0615E-06	4.2266E-07	0	0	0	0.000123331
Forager (TL-III)	lobster	2.833E-11	2.2824E-06	3.8328E-06	0.0001363	0.00014316	5.6849E-06	1.0697E-06	0	0	0	0.00029233
Predator (TL-IV)	flounder	5.7795E-12	1.4022E-06	4.0594E-06	0.00029587	0.00062835	3.2115E-05	6.2582E-06	0	0	0	0.000968053

FIGURE F 10 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 month
Scenario run on	5/10/2005	14:05	Distance Interval	15 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	2.5702E-16	1.3824E-13	9.4542E-13	2.1602E-11	3.3855E-11	1.6883E-12	5.3727E-14	0	0	0	5.82831E-11
Zooplankton (TL-II)	copepods	2.2587E-10	1.4019E-07	1.1909E-06	3.2034E-05	3.1811E-05	2.3885E-06	6.3674E-08	0	0	0	6.76289E-05
Planktivore (TL-III)	herring	6.7878E-11	1.5796E-07	2.425E-06	0.00012642	0.00022558	1.866E-05	4.8541E-07	0	0	0	0.000373723
Piscivore (TL-IV)	jack	1.7742E-11	2.7833E-08	6.4374E-07	7.3839E-05	0.00039541	5.6028E-05	1.6434E-06	0	0	0	0.000527592
Reef / Vessel Community												
Attached Algae	Algae	3.1179E-11	1.4032E-08	9.9996E-08	2.3685E-06	3.736E-06	1.9395E-07	3.722E-09	0	0	0	6.41618E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	5.4822E-10	3.0911E-07	2.5711E-06	6.8903E-05	6.6807E-05	3.1257E-06	6.7929E-08	0	0	0	0.000141784
Invertibrate Omnivore (TL-II)	urchin	1.6706E-08	2.1642E-05	0.00026894	0.01231871	0.01988012	0.00074616	1.1814E-05	0	0	0	0.033247415
Invertibrate Forager (TL-III)	crab	5.7376E-08	3.4524E-05	0.00039197	0.01601416	0.02783546	0.00120324	2.1006E-05	0	0	0	0.045500424
Vertibrate Forager (TL-III)	triggerfish	1.4538E-08	1.0914E-05	0.00014493	0.00767909	0.0227114	0.00138023	2.7266E-05	0	0	0	0.031953844
Predator (TL-IV)	grouper	8.2783E-09	6.2332E-06	8.2988E-05	0.00448514	0.01763831	0.0014415	3.164E-05	0	0	0	0.023685826
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.4764E-10	9.732E-08	8.4863E-07	2.3921E-05	2.4057E-05	1.1608E-06	4.4484E-08	0	0	0	5.01287E-05
Epifaunal invert. (TL-II)	nematode	2.0601E-10	2.0337E-07	2.0372E-06	6.5706E-05	7.2528E-05	3.6644E-06	1.2342E-07	0	0	0	0.000144263
Forager (TL-III)	lobster	2.667E-10	2.4664E-07	3.1709E-06	0.00013655	0.00020384	1.0081E-05	3.0281E-07	0	0	0	0.0003542
Predator (TL-IV)	flounder	5.4409E-11	1.5155E-07	3.3584E-06	0.00029642	0.00089471	5.6943E-05	1.7638E-06	0	0	0	0.001253345

FIGURE F 11 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 month
Scenario run on	5/10/2005	14:09	Distance Interval	45 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	4.2055E-16	2.262E-13	1.5469E-12	3.5347E-11	5.5394E-11	2.7622E-12	8.7973E-14	0	0	0	9.53647E-11
Zooplankton (TL-II)	copepods	1.9469E-10	1.2084E-07	1.0265E-06	2.7612E-05	2.742E-05	2.0585E-06	5.4946E-08	0	0	0	5.82924E-05
Planktivore (TL-III)	herring	5.8507E-11	1.3615E-07	2.0903E-06	0.00010896	0.00019444	1.6082E-05	4.1887E-07	0	0	0	0.000322129
Piscivore (TL-IV)	jack	1.5293E-11	2.3991E-08	5.5488E-07	6.3645E-05	0.00034083	4.8288E-05	1.4181E-06	0	0	0	0.000454755
Reef / Vessel Community												
Attached Algae	Algae	2.6874E-11	1.2095E-08	8.619E-08	2.0415E-06	3.2202E-06	1.6715E-07	3.2114E-09	0	0	0	5.5303E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	4.7253E-10	2.6644E-07	2.2161E-06	5.939E-05	5.7583E-05	2.6939E-06	5.8615E-08	0	0	0	0.000122209
Invertibrate Omnivore (TL-II)	urchin	1.6691E-08	2.1613E-05	0.00026853	0.01229685	0.01983608	0.00074381	1.1767E-05	0	0	0	0.033178661
Invertibrate Forager (TL-III)	crab	5.7349E-08	3.4492E-05	0.00039151	0.01598926	0.02778555	0.00120044	2.0942E-05	0	0	0	0.045422253
Vertibrate Forager (TL-III)	triggerfish	1.453E-08	1.0893E-05	0.00014448	0.00763969	0.02259184	0.00137161	2.7024E-05	0	0	0	0.031785562
Predator (TL-IV)	grouper	8.2717E-09	6.2213E-06	8.2729E-05	0.0044597	0.01753336	0.00143253	3.1363E-05	0	0	0	0.023545907
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.2726E-10	8.3885E-08	7.3146E-07	2.0618E-05	2.0735E-05	1.0004E-06	3.8333E-08	0	0	0	4.32078E-05
Epifaunal invert. (TL-II)	nematode	1.7757E-10	1.7529E-07	1.756E-06	5.6634E-05	6.2515E-05	3.1582E-06	1.0638E-07	0	0	0	0.000124346
Forager (TL-III)	lobster	2.2988E-10	2.1259E-07	2.7331E-06	0.0001177	0.0001757	8.6884E-06	2.6102E-07	0	0	0	0.000305298
Predator (TL-IV)	flounder	4.6897E-11	1.3062E-07	2.8947E-06	0.00025549	0.00077119	4.9075E-05	1.5205E-06	0	0	0	0.0010803

FIGURE F 12 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 month
Scenario run on	5/12/2005	14:11	Distance Interval	60 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	4.8286E-16	2.5971E-13	1.7761E-12	4.0584E-11	6.3602E-11	3.1713E-12	1.0104E-13	0	0	0	1.09494E-10
Zooplankton (TL-II)	copepods	1.828E-10	1.1347E-07	9.6387E-07	2.5926E-05	2.5746E-05	1.9328E-06	5.162E-08	0	0	0	5.47348E-05
Planktivore (TL-III)	herring	5.4937E-11	1.2784E-07	1.9627E-06	0.00010231	0.00018257	1.51E-05	3.9352E-07	0	0	0	0.000302469
Piscivore (TL-IV)	jack	1.436E-11	2.2527E-08	5.2101E-07	5.9761E-05	0.00032003	4.5338E-05	1.3323E-06	0	0	0	0.000427001
Reef / Vessel Community												
Attached Algae	Algae	2.5234E-11	1.1357E-08	8.093E-08	1.9169E-06	3.0236E-06	1.5694E-07	3.0168E-09	0	0	0	5.19275E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	4.4368E-10	2.5018E-07	2.0809E-06	5.5765E-05	5.4069E-05	2.5293E-06	5.5066E-08	0	0	0	0.00011475
Invertibrate Omnivore (TL-II)	urchin	1.6686E-08	2.1602E-05	0.00026837	0.01228851	0.0198193	0.00074291	1.1749E-05	0	0	0	0.033152463
Invertibrate Forager (TL-III)	crab	5.7339E-08	3.4479E-05	0.00039133	0.01597978	0.02776654	0.00119937	2.0918E-05	0	0	0	0.045392467
Vertibrate Forager (TL-III)	triggerfish	1.4527E-08	1.0885E-05	0.00014431	0.00762468	0.02254629	0.00136833	2.6931E-05	0	0	0	0.031721439
Predator (TL-IV)	grouper	8.2691E-09	6.2168E-06	8.263E-05	0.00445	0.01749337	0.00142911	3.1257E-05	0	0	0	0.023492592
Benthic Community												
Infaunal invert. (TL-II)	polychaete	1.1949E-10	7.8766E-08	6.8682E-07	1.936E-05	1.947E-05	9.3928E-07	3.599E-08	0	0	0	4.05706E-05
Epifaunal invert. (TL-II)	nematode	1.6673E-10	1.6459E-07	1.6488E-06	5.3178E-05	5.87E-05	2.9652E-06	9.9891E-08	0	0	0	0.000116756
Forager (TL-III)	lobster	2.1585E-10	1.9962E-07	2.5663E-06	0.00011052	0.00016498	8.1577E-06	2.451E-07	0	0	0	0.000286664
Predator (TL-IV)	flounder	4.4034E-11	1.2265E-07	2.7181E-06	0.0002399	0.00072412	4.6077E-05	1.4277E-06	0	0	0	0.001014363

FIGURE F 13 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	6 months	
Scenario run on	5/10/2005	14:10	Distance Interval	15 meters	

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	1.498E-16	7.7302E-14	4.6818E-13	1.4418E-11	2.9294E-11	2.2555E-12	6.1343E-14	0	3.1971E-16	1.982E-17	4.65747E-11
Zooplankton (TL-II)	copepods	1.3013E-10	8.3386E-08	5.5001E-07	2.0887E-05	2.8487E-05	3.2132E-06	1.2861E-07	0	1.4767E-09	3.0227E-10	5.33509E-05
Planktivore (TL-III)	herring	3.9107E-11	9.3953E-08	1.12E-06	8.2427E-05	0.000202	2.5103E-05	9.8052E-07	0	7.471E-09	5.7564E-10	0.000311734
Piscivore (TL-IV)	jack	1.0222E-11	1.6555E-08	2.973E-07	4.8145E-05	0.00035408	7.5375E-05	3.3197E-06	0	2.2464E-08	8.0972E-10	0.00048126
Reef / Vessel Community												
Attached Algae	Algae	1.7963E-11	8.3461E-09	4.6182E-08	1.5443E-06	3.3455E-06	2.6095E-07	7.5222E-09	0	4.3225E-11	5.6155E-12	5.21289E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	3.1585E-10	1.8386E-07	1.1874E-06	4.4927E-05	5.9824E-05	4.2052E-06	1.3723E-07	0	1.0046E-09	1.5082E-10	0.000110466
Invertibrate Omnivore (TL-II)	urchin	9.6251E-09	1.2873E-05	0.00012421	0.00803218	0.01780236	0.00100376	2.3902E-05	0	4.0717E-08	1.3154E-09	0.026999337
Invertibrate Forager (TL-III)	crab	3.3163E-08	2.1512E-05	0.00019679	0.01211784	0.03013091	0.00193165	4.9777E-05	0	1.5459E-07	1.7037E-08	0.044448692
Vertibrate Forager (TL-III)	triggerfish	8.636E-09	8.2807E-06	0.00010036	0.00970568	0.04324331	0.00361917	9.9935E-05	0	3.7517E-07	3.8634E-08	0.05677715
Predator (TL-IV)	grouper	4.8777E-09	4.4079E-06	5.2773E-05	0.00552822	0.03820171	0.0045	0.00013803	0	6.3568E-07	6.3806E-08	0.048425837
Benthic Community												
Infaunal invert. (TL-II)	polychaete	8.5068E-11	5.8036E-08	3.9231E-07	1.5604E-05	2.1547E-05	1.5593E-06	6.8089E-08	0	3.5017E-10	3.6976E-11	3.92287E-05
Epifaunal invert. (TL-II)	nematode	1.187E-10	1.2119E-07	9.4152E-07	4.2855E-05	6.4958E-05	4.9246E-06	2.0096E-07	0	9.839E-10	7.857E-11	0.000114003
Forager (TL-III)	lobster	1.5366E-10	1.4686E-07	1.4651E-06	8.9059E-05	0.00018256	1.3551E-05	5.0165E-07	0	1.619E-09	6.4307E-11	0.000287287
Predator (TL-IV)	flounder	3.1347E-11	9.0245E-08	1.5518E-06	0.00019332	0.0008013	7.6541E-05	2.9292E-06	0	7.6746E-09	2.3379E-10	0.001075737

FIGURE F 14 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	6 months
Scenario run on	5/10/2005	14:10	Distance Interval	45 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	2.4511E-16	1.2648E-13	7.6605E-13	2.3591E-11	4.7932E-11	3.6905E-12	1.0037E-13	0	5.2309E-16	3.2429E-17	7.62074E-11
Zooplankton (TL-II)	copepods	1.1217E-10	7.1874E-08	4.7408E-07	1.8004E-05	2.4554E-05	2.7696E-06	1.1086E-07	0	1.2727E-09	2.6051E-10	4.59856E-05
Planktivore (TL-III)	herring	3.3708E-11	8.0982E-08	9.6536E-07	7.1048E-05	0.00017412	2.1637E-05	8.4513E-07	0	6.439E-09	4.9611E-10	0.000268699
Piscivore (TL-IV)	jack	8.8109E-12	1.4269E-08	2.5626E-07	4.1499E-05	0.0003052	6.4969E-05	2.8614E-06	0	1.9361E-08	6.9783E-10	0.000414822
Reef / Vessel Community												
Attached Algae	Algae	1.5483E-11	7.1938E-09	3.9806E-08	1.3311E-06	2.8836E-06	2.2492E-07	6.4834E-09	0	3.7253E-11	4.8389E-12	4.49316E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	2.7224E-10	1.5847E-07	1.0235E-06	3.8724E-05	5.1565E-05	3.6246E-06	1.1828E-07	0	8.6579E-10	1.2998E-10	9.52153E-05
Invertibrate Omnivore (TL-II)	urchin	9.6166E-09	1.2855E-05	0.00012402	0.00801792	0.01776292	0.0010006	2.3807E-05	0	4.0317E-08	1.2952E-09	0.026942171
Invertibrate Forager (TL-III)	crab	3.3147E-08	2.1492E-05	0.00019655	0.01209907	0.03007586	0.001927	4.9631E-05	0	1.5408E-07	1.7017E-08	0.044369814
Vertibrate Forager (TL-III)	triggerfish	8.6314E-09	8.2682E-06	0.00010015	0.00967878	0.04311933	0.00360573	9.9458E-05	0	3.7345E-07	3.858E-08	0.056612132
Predator (TL-IV)	grouper	4.8739E-09	4.4012E-06	5.2656E-05	0.00551034	0.03807773	0.00448255	0.00013735	0	6.3328E-07	6.3727E-08	0.048265729
Benthic Community												
Infaunal invert. (TL-II)	polychaete	7.3323E-11	5.0023E-08	3.3814E-07	1.3449E-05	1.8572E-05	1.344E-06	5.8655E-08	0	3.018E-10	3.1869E-11	3.38128E-05
Epifaunal invert. (TL-II)	nematode	1.0231E-10	1.0445E-07	8.1154E-07	3.6939E-05	5.599E-05	4.2447E-06	1.7314E-07	0	8.4799E-10	6.7717E-11	9.82637E-05
Forager (TL-III)	lobster	1.3244E-10	1.2659E-07	1.2629E-06	7.6763E-05	0.00015736	1.168E-05	4.3222E-07	0	1.3953E-09	5.5421E-11	0.000247623
Predator (TL-IV)	flounder	2.7019E-11	7.7785E-08	1.3376E-06	0.00016663	0.00069067	6.5973E-05	2.5238E-06	0	6.6144E-09	2.0147E-10	0.000927218

FIGURE F 15 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier	N/A	Time Interval	6 months
Scenario run on 5/12/2005	14:12	Distance Interval	60 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	2.8143E-16	1.4522E-13	8.7955E-13	2.7086E-11	5.5034E-11	4.2374E-12	1.1524E-13	0	6.0058E-16	3.7233E-17	8.74987E-11
Zooplankton (TL-II)	copepods	1.0532E-10	6.7488E-08	4.4515E-07	1.6905E-05	2.3055E-05	2.6006E-06	1.0409E-07	0	1.195E-09	2.446E-10	4.31792E-05
Planktivore (TL-III)	herring	3.1651E-11	7.604E-08	9.0644E-07	6.6712E-05	0.00016349	2.0317E-05	7.9355E-07	0	6.0457E-09	4.6581E-10	0.000252301
Piscivore (TL-IV)	jack	8.2732E-12	1.3399E-08	2.4062E-07	3.8966E-05	0.00028658	6.1003E-05	2.6867E-06	0	1.8179E-08	6.552E-10	0.000389506
Reef / Vessel Community												
Attached Algae	Algae	1.4538E-11	6.7547E-09	3.7376E-08	1.2499E-06	2.7076E-06	2.1119E-07	6.0876E-09	0	3.4977E-11	4.543E-12	4.21892E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	2.5562E-10	1.488E-07	9.6101E-07	3.6361E-05	4.8418E-05	3.4033E-06	1.1106E-07	0	8.1291E-10	1.2204E-10	8.94039E-05
Invertibrate Omnivore (TL-II)	urchin	9.6133E-09	1.2849E-05	0.00012394	0.00801249	0.01774789	0.00099939	2.377E-05	0	4.0164E-08	1.2875E-09	0.026920388
Invertibrate Forager (TL-III)	crab	3.3141E-08	2.1484E-05	0.00019646	0.01209192	0.03005488	0.00192523	4.9575E-05	0	1.5389E-07	1.7009E-08	0.044339758
Vertibrate Forager (TL-III)	triggerfish	8.6297E-09	8.2635E-06	0.00010007	0.00966852	0.04307208	0.00360061	9.9276E-05	0	3.7279E-07	3.856E-08	0.056549252
Predator (TL-IV)	grouper	4.8725E-09	4.3987E-06	5.2612E-05	0.00550352	0.03803049	0.00447591	0.00013709	0	6.3236E-07	6.3697E-08	0.048204721
Benthic Community												
Infaunal invert. (TL-II)	polychaete	6.8847E-11	4.697E-08	3.1751E-07	1.2629E-05	1.7439E-05	1.262E-06	5.506E-08	0	2.8337E-10	2.9922E-11	3.1749E-05
Epifaunal invert. (TL-II)	nematode	9.6065E-11	9.8079E-08	7.6201E-07	3.4684E-05	5.2573E-05	3.9856E-06	1.6254E-07	0	7.962E-10	6.3581E-11	9.22663E-05
Forager (TL-III)	lobster	1.2436E-10	1.1886E-07	1.1858E-06	7.2078E-05	0.00014775	1.0967E-05	4.0576E-07	0	1.3101E-09	5.2035E-11	0.00023251
Predator (TL-IV)	flounder	2.537E-11	7.3037E-08	1.2559E-06	0.00015646	0.00064851	6.1946E-05	2.3693E-06	0	6.2104E-09	1.8916E-10	0.000870625

FIGURE F 16 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier	N/A	Time Interval	1 year
Scenario run on	5/10/2005 14:11	Distance Interval	15 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	1.3629E-16	1.8165E-15	2.4019E-13	7.3594E-12	1.293E-11	8.9173E-13	1.2302E-14	0	3.0091E-22	2.6751E-23	2.14354E-11
Zooplankton (TL-II)	copepods	1.1981E-10	1.9282E-09	3.1745E-07	1.0636E-05	1.1355E-05	1.1345E-06	1.9887E-08	0	3.5503E-18	1.0419E-18	2.34653E-05
Planktivore (TL-III)	herring	3.6006E-11	2.1725E-09	6.4641E-07	4.1974E-05	8.052E-05	8.8634E-06	1.5161E-07	0	1.7822E-17	1.8626E-18	0.000132158
Piscivore (TL-IV)	jack	9.4115E-12	3.8281E-10	1.7159E-07	2.4517E-05	0.00014114	2.6613E-05	5.133E-07	0	5.322E-17	2.306E-18	0.000192956
Reef / Vessel Community												
Attached Algae	Algae	1.6539E-11	1.9299E-10	2.6655E-08	7.8642E-07	1.3335E-06	9.2136E-08	1.163E-09	0	8.9758E-20	7.9795E-21	2.24012E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	2.9081E-10	4.2515E-09	6.8534E-07	2.2878E-05	2.3846E-05	1.4848E-06	2.1218E-08	0	2.3916E-18	5.1482E-19	4.89206E-05
Invertibrate Omnivore (TL-II)	urchin	8.8628E-09	2.9886E-07	7.1703E-05	0.00409265	0.007106	0.0003549	3.7143E-06	0	6.5919E-18	4.1408E-19	0.011629279
Invertibrate Forager (TL-III)	crab	3.0632E-08	5.2201E-07	0.00012266	0.00702691	0.01410287	0.00079359	8.886E-06	0	4.4317E-11	3.018E-12	0.022055467
Vertibrate Forager (TL-III)	triggerfish	8.063E-09	2.1026E-07	6.6811E-05	0.00617192	0.0224631	0.00164196	1.9727E-05	0	4.1973E-10	1.8998E-11	0.030363737
Predator (TL-IV)	grouper	4.5543E-09	1.1489E-07	3.7922E-05	0.00432449	0.02788388	0.00293187	3.8882E-05	0	1.2141E-09	3.3335E-11	0.035217167
Benthic Community												
Infaunal invert. (TL-II)	polychaete	7.8323E-11	1.7125E-09	2.2666E-07	7.9544E-06	8.6311E-06	5.9029E-07	2.7335E-08	0	1.0527E-10	2.2077E-11	1.74317E-05
Epifaunal invert. (TL-II)	nematode	1.0929E-10	3.3523E-09	5.4382E-07	2.184E-05	2.5986E-05	1.8278E-06	6.8399E-08	0	1.9969E-10	3.3257E-11	5.02702E-05
Forager (TL-III)	lobster	1.4148E-10	3.7899E-09	8.4608E-07	4.5379E-05	7.2973E-05	4.9891E-06	1.6254E-07	0	3.2811E-10	2.527E-11	0.000124354
Predator (TL-IV)	flounder	2.8862E-11	2.3468E-09	8.9614E-07	9.8507E-05	0.0003203	2.8168E-05	9.4243E-07	0	1.4461E-09	5.6599E-11	0.000448812

FIGURE F 17 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 year
Scenario run on	5/10/2005	14:11	Distance Interval	45 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	2.23E-16	2.9723E-15	3.93E-13	1.2042E-11	2.1157E-11	1.4591E-12	2.0132E-14	0	5.0074E-22	4.4496E-23	3.50736E-11
Zooplankton (TL-II)	copepods	1.0327E-10	1.662E-09	2.7362E-07	9.168E-06	9.7875E-06	9.7791E-07	1.7143E-08	0	5.8964E-18	1.7297E-18	2.02259E-05
Planktivore (TL-III)	herring	3.1036E-11	1.8726E-09	5.5717E-07	3.618E-05	6.9404E-05	7.6399E-06	1.307E-07	0	2.9599E-17	3.092E-18	0.000113914
Piscivore (TL-IV)	jack	8.1123E-12	3.2997E-10	1.4791E-07	2.1133E-05	0.00012166	2.294E-05	4.4249E-07	0	8.8388E-17	3.8281E-18	0.00016632
Reef / Vessel Community												
Attached Algae	Algae	1.4256E-11	1.6635E-10	2.2975E-08	6.7784E-07	1.1494E-06	7.9416E-08	1.0025E-09	0	1.4907E-19	1.3246E-20	1.93084E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	2.5066E-10	3.6645E-09	5.9072E-07	1.972E-05	2.0554E-05	1.2798E-06	1.8291E-08	0	3.972E-18	8.5462E-19	4.21666E-05
Invertibrate Omnivore (TL-II)	urchin	8.8549E-09	2.9846E-07	7.1592E-05	0.00408539	0.00709028	0.00035378	3.6996E-06	0	1.0948E-17	6.8738E-19	0.011605055
Invertibrate Forager (TL-III)	crab	3.0618E-08	5.2152E-07	0.00012252	0.00701627	0.01407703	0.00079165	8.8582E-06	0	3.8198E-11	2.6013E-12	0.022016885
Vertibrate Forager (TL-III)	triggerfish	8.0587E-09	2.0995E-07	6.6685E-05	0.00615723	0.02240699	0.00163651	1.9627E-05	0	3.6178E-10	1.6375E-11	0.030287264
Predator (TL-IV)	grouper	4.5509E-09	1.1473E-07	3.7851E-05	0.0043134	0.02781055	0.00292219	3.8667E-05	0	1.0465E-09	2.8732E-11	0.035122781
Benthic Community												
Infaunal invert. (TL-II)	polychaete	6.7509E-11	1.4761E-09	1.9537E-07	6.8562E-06	7.4395E-06	5.088E-07	2.3529E-08	0	9.0734E-11	1.9029E-11	1.50251E-05
Epifaunal invert. (TL-II)	nematode	9.4198E-11	2.8895E-09	4.6874E-07	1.8825E-05	2.2399E-05	1.5755E-06	5.8885E-08	0	1.7212E-10	2.8665E-11	4.33299E-05
Forager (TL-III)	lobster	1.2194E-10	3.2667E-09	7.2926E-07	3.9114E-05	6.2898E-05	4.3004E-06	1.3994E-07	0	2.8281E-10	2.1781E-11	0.000107186
Predator (TL-IV)	flounder	2.4877E-11	2.0228E-09	7.7241E-07	8.4907E-05	0.00027608	2.4279E-05	8.114E-07	0	1.2465E-09	4.8785E-11	0.000386848

FIGURE F 18 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	1 year
Scenario run on	5/12/2005	14:13	Distance Interval	60 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	2.5604E-16	3.4127E-15	4.5123E-13	1.3826E-11	2.4291E-11	1.6753E-12	2.3115E-14	0	5.7966E-22	5.1497E-23	4.02704E-11
Zooplankton (TL-II)	copepods	9.697E-11	1.5606E-09	2.5692E-07	8.6085E-06	9.1902E-06	9.1824E-07	1.6098E-08	0	6.8192E-18	1.9999E-18	1.89915E-05
Planktivore (TL-III)	herring	2.9142E-11	1.7584E-09	5.2317E-07	3.3972E-05	6.5169E-05	7.1737E-06	1.2273E-07	0	3.4231E-17	3.5751E-18	0.000106962
Piscivore (TL-IV)	jack	7.6173E-12	3.0983E-10	1.3888E-07	1.9843E-05	0.00011423	2.154E-05	4.1551E-07	0	1.0222E-16	4.4262E-18	0.00015617
Reef / Vessel Community												
Attached Algae	Algae	1.3385E-11	1.562E-10	2.1572E-08	6.3647E-07	1.0793E-06	7.4569E-08	9.4139E-10	0	1.724E-19	1.5316E-20	1.81299E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	2.3536E-10	3.4409E-09	5.5466E-07	1.8516E-05	1.93E-05	1.2017E-06	1.7176E-08	0	4.5936E-18	9.8815E-19	3.9593E-05
Invertibrate Omnivore (TL-II)	urchin	8.8519E-09	2.983E-07	7.155E-05	0.00408262	0.00708429	0.00035336	3.694E-06	0	1.2661E-17	7.9478E-19	0.011595824
Invertibrate Forager (TL-III)	crab	3.0612E-08	5.2134E-07	0.00012247	0.00701222	0.01406719	0.00079091	8.8476E-06	0	3.5867E-11	2.4425E-12	0.022002184
Vertibrate Forager (TL-III)	triggerfish	8.057E-09	2.0983E-07	6.6638E-05	0.00615163	0.02238561	0.00163444	1.9588E-05	0	3.397E-10	1.5376E-11	0.030258124
Predator (TL-IV)	grouper	4.5496E-09	1.1467E-07	3.7823E-05	0.00430917	0.02778261	0.00291851	3.8586E-05	0	9.8262E-10	2.6979E-11	0.035086815
Benthic Community												
Infaunal invert. (TL-II)	polychaete	6.3389E-11	1.386E-09	1.8344E-07	6.4377E-06	6.9855E-06	4.7775E-07	2.2079E-08	0	8.5196E-11	1.7868E-11	1.4108E-05
Epifaunal invert. (TL-II)	nematode	8.8448E-11	2.7131E-09	4.4013E-07	1.7676E-05	2.1032E-05	1.4793E-06	5.526E-08	0	1.6161E-10	2.6916E-11	4.06853E-05
Forager (TL-III)	lobster	1.145E-10	3.0673E-09	6.8475E-07	3.6727E-05	5.906E-05	4.0379E-06	1.3133E-07	0	2.6555E-10	2.0452E-11	0.000100644
Predator (TL-IV)	flounder	2.3359E-11	1.8993E-09	7.2527E-07	7.9725E-05	0.00025923	2.2797E-05	7.6147E-07	0	1.1704E-09	4.5807E-11	0.000363237

FIGURE F 19 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	2 years
Scenario run on	5/10/2005	14:11	Distance Interval	15 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	1.0073E-16	2.5308E-12	2.5081E-13	4.1305E-12	6.9022E-12	6.3273E-13	2.3549E-13	0	9.3518E-16	5.8025E-17	1.46835E-11
Zooplankton (TL-II)	copepods	8.8555E-11	3.0793E-06	3.4411E-07	6.4825E-06	6.9235E-06	8.6468E-07	5.0911E-07	0	4.4877E-09	9.1859E-10	1.82086E-05
Planktivore (TL-III)	herring	2.6612E-11	3.4695E-06	7.0069E-07	2.5582E-05	4.9095E-05	6.7553E-06	3.8813E-06	0	2.2704E-08	1.7494E-09	8.95083E-05
Piscivore (TL-IV)	jack	6.956E-12	6.1133E-07	1.86E-07	1.4942E-05	8.6057E-05	2.0283E-05	1.3141E-05	0	6.827E-08	2.461E-09	0.000135292
Reef / Vessel Community												
Attached Algae	Algae	1.2224E-11	3.082E-07	2.8893E-08	4.793E-07	8.131E-07	7.0222E-08	2.9776E-08	0	1.3137E-10	1.7071E-11	1.72965E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	2.1493E-10	6.7895E-06	7.4289E-07	1.3944E-05	1.454E-05	1.1316E-06	5.4321E-07	0	3.0528E-09	4.5834E-10	3.76943E-05
Invertibrate Omnivore (TL-II)	urchin	6.5558E-09	0.00047408	7.7686E-05	0.00249597	0.00432924	0.00027009	9.436E-05	0	1.2342E-07	3.9879E-09	0.00774156
Invertibrate Forager (TL-III)	crab	2.273E-08	0.00086384	0.00014275	0.00480626	0.00985783	0.00068817	0.0002544	0	5.1798E-07	5.2199E-08	0.016613838
Vertibrate Forager (TL-III)	triggerfish	6.1478E-09	0.00040155	9.571E-05	0.00559655	0.02139225	0.00191223	0.00074426	0	1.5916E-06	1.326E-07	0.030144268
Predator (TL-IV)	grouper	3.402E-09	0.00020604	5.3988E-05	0.00469875	0.03899121	0.00527572	0.0022562	0	4.6598E-06	2.7407E-07	0.051486848
Benthic Community												
Infaunal invert. (TL-II)	polychaete	5.7892E-11	2.1293E-06	2.4563E-07	4.8541E-06	5.2856E-06	4.6271E-07	2.108E-07	0	9.771E-10	9.4177E-11	1.31892E-05
Epifaunal invert. (TL-II)	nematode	8.0777E-11	4.4545E-06	5.8938E-07	1.3323E-05	1.5895E-05	1.4218E-06	6.6506E-07	0	2.8249E-09	2.1137E-10	3.63521E-05
Forager (TL-III)	lobster	1.0457E-10	5.4086E-06	9.17E-07	2.7677E-05	4.4604E-05	3.8684E-06	1.6888E-06	0	4.6488E-09	1.7462E-10	8.41686E-05
Predator (TL-IV)	flounder	2.1332E-11	3.3228E-06	9.7125E-07	6.0081E-05	0.00019578	2.1837E-05	9.8845E-06	0	2.2127E-08	6.6396E-10	0.000291896

FIGURE F 20 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	2 years
Scenario run on	5/10/2005	14:12	Distance Interval	45 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	1.6482E-16	4.141E-12	4.1038E-13	6.7584E-12	1.1294E-11	1.0353E-12	3.8532E-13	0	1.5302E-15	9.4941E-17	2.40258E-11
Zooplankton (TL-II)	copepods	7.6329E-11	2.6541E-06	2.966E-07	5.5876E-06	5.9677E-06	7.4531E-07	4.3882E-07	0	3.8681E-09	7.9176E-10	1.56948E-05
Planktivore (TL-III)	herring	2.2939E-11	2.9905E-06	6.0396E-07	2.205E-05	4.2318E-05	5.8227E-06	3.3455E-06	0	1.9569E-08	1.5079E-09	7.71515E-05
Piscivore (TL-IV)	jack	5.9958E-12	5.2693E-07	1.6033E-07	1.288E-05	7.4177E-05	1.7483E-05	1.1327E-05	0	5.8844E-08	2.1212E-09	0.000116615
Reef / Vessel Community												
Attached Algae	Algae	1.0536E-11	2.6565E-07	2.4904E-08	4.1312E-07	7.0084E-07	6.0527E-08	2.5665E-08	0	1.1323E-10	1.4714E-11	1.49084E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	1.8526E-10	5.8521E-06	6.4032E-07	1.2018E-05	1.2532E-05	9.7539E-07	4.6821E-07	0	2.6313E-09	3.9505E-10	3.24902E-05
Invertibrate Omnivore (TL-II)	urchin	6.55E-09	0.00047343	7.7566E-05	0.00249155	0.00431966	0.00026924	9.3983E-05	0	1.222E-07	3.9266E-09	0.007725554
Invertibrate Forager (TL-III)	crab	2.272E-08	0.00086304	0.00014258	0.004799	0.00983953	0.00068645	0.00025363	0	5.1603E-07	5.213E-08	0.016584826
Vertibrate Forager (TL-III)	triggerfish	6.1447E-09	0.00040106	9.5565E-05	0.00558612	0.02134789	0.00190689	0.00074171	0	1.5853E-06	1.3242E-07	0.03008096
Predator (TL-IV)	grouper	3.3996E-09	0.00020584	5.3919E-05	0.00469068	0.03891387	0.00526183	0.00224904	0	4.6451E-06	2.738E-07	0.051380094
Benthic Community												
Infaunal invert. (TL-II)	polychaete	4.9899E-11	1.8353E-06	2.1172E-07	4.1839E-06	4.5559E-06	3.9883E-07	1.8166E-07	0	8.4219E-10	8.1174E-11	1.13683E-05
Epifaunal invert. (TL-II)	nematode	6.9625E-11	3.8395E-06	5.08E-07	1.1484E-05	1.3701E-05	1.2255E-06	5.7317E-07	0	2.4349E-09	1.8218E-10	3.13332E-05
Forager (TL-III)	lobster	9.0129E-11	4.6619E-06	7.904E-07	2.3856E-05	3.8446E-05	3.3344E-06	1.4555E-06	0	4.0069E-09	1.5051E-10	7.25479E-05
Predator (TL-IV)	flounder	1.8387E-11	2.864E-06	8.3716E-07	5.1786E-05	0.00016875	1.8822E-05	8.5188E-06	0	1.9072E-08	5.7228E-10	0.000251595

FIGURE F 21 - PCB MODELING RESULTS - PROSPECTIVE RISK EVALUATION
TIME DYNAMIC MODEL OUTPUT

Fish Tissue (wet weight) Concentrations for Ex-ORISKANY CV34

Zone of Influence Multiplier		N/A	Time Interval	2 years
Scenario run on	5/12/2005	14:13	Distance Interval	60 meters

		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCB
Pelagic Community												
Phytoplankton (TL1)	Algae	1.8924E-16	4.7545E-12	4.7119E-13	7.7598E-12	1.2967E-11	1.1887E-12	4.424E-13	0	1.7569E-15	1.0901E-16	2.75856E-11
Zooplankton (TL-II)	copepods	7.1671E-11	2.4922E-06	2.785E-07	5.2466E-06	5.6035E-06	6.9982E-07	4.1204E-07	0	3.632E-09	7.4343E-10	1.4737E-05
Planktivore (TL-III)	herring	2.1539E-11	2.808E-06	5.671E-07	2.0704E-05	3.9735E-05	5.4674E-06	3.1413E-06	0	1.8375E-08	1.4158E-09	7.2443E-05
Piscivore (TL-IV)	jack	5.6299E-12	4.9478E-07	1.5054E-07	1.2093E-05	6.965E-05	1.6416E-05	1.0635E-05	0	5.5252E-08	1.9917E-09	0.000109498
Reef / Vessel Community												
Attached Algae	Algae	9.8932E-12	2.4944E-07	2.3384E-08	3.8791E-07	6.5806E-07	5.6832E-08	2.4098E-08	0	1.0632E-10	1.3815E-11	1.39985E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	1.7395E-10	5.4949E-06	6.0124E-07	1.1285E-05	1.1768E-05	9.1586E-07	4.3963E-07	0	2.4707E-09	3.7094E-10	3.05071E-05
Invertibrate Omnivore (TL-II)	urchin	6.5477E-09	0.00047319	7.7521E-05	0.00248986	0.004316	0.00026891	9.384E-05	0	1.2174E-07	3.9032E-09	0.007719456
Invertibrate Forager (TL-III)	crab	2.2716E-08	0.00086273	0.00014252	0.00479624	0.00983256	0.0006858	0.00025334	0	5.1528E-07	5.2103E-08	0.016573771
Vertibrate Forager (TL-III)	triggerfish	6.1435E-09	0.00040087	9.551E-05	0.00558215	0.02133099	0.00190486	0.00074073	0	1.5829E-06	1.3236E-07	0.030056837
Predator (TL-IV)	grouper	3.3987E-09	0.00020576	5.3893E-05	0.0046876	0.0388844	0.00525654	0.00224631	0	4.6395E-06	2.737E-07	0.051339417
Benthic Community												
Infaunal invert. (TL-II)	polychaete	4.6854E-11	1.7233E-06	1.9879E-07	3.9286E-06	4.2778E-06	3.7449E-07	1.7056E-07	0	7.9079E-10	7.6219E-11	1.06744E-05
Epifaunal invert. (TL-II)	nematode	6.5375E-11	3.6052E-06	4.77E-07	1.0783E-05	1.2864E-05	1.1507E-06	5.3815E-07	0	2.2863E-09	1.7106E-10	2.94208E-05
Forager (TL-III)	lobster	8.4628E-11	4.3773E-06	7.4215E-07	2.24E-05	3.6099E-05	3.1309E-06	1.3666E-06	0	3.7623E-09	1.4132E-10	6.81199E-05
Predator (TL-IV)	flounder	1.7265E-11	2.6892E-06	7.8606E-07	4.8625E-05	0.00015845	1.7673E-05	7.9984E-06	0	1.7908E-08	5.3734E-10	0.000236239

Figure G 1 – Average Total PCBs in Water above Pycnocline around Ship

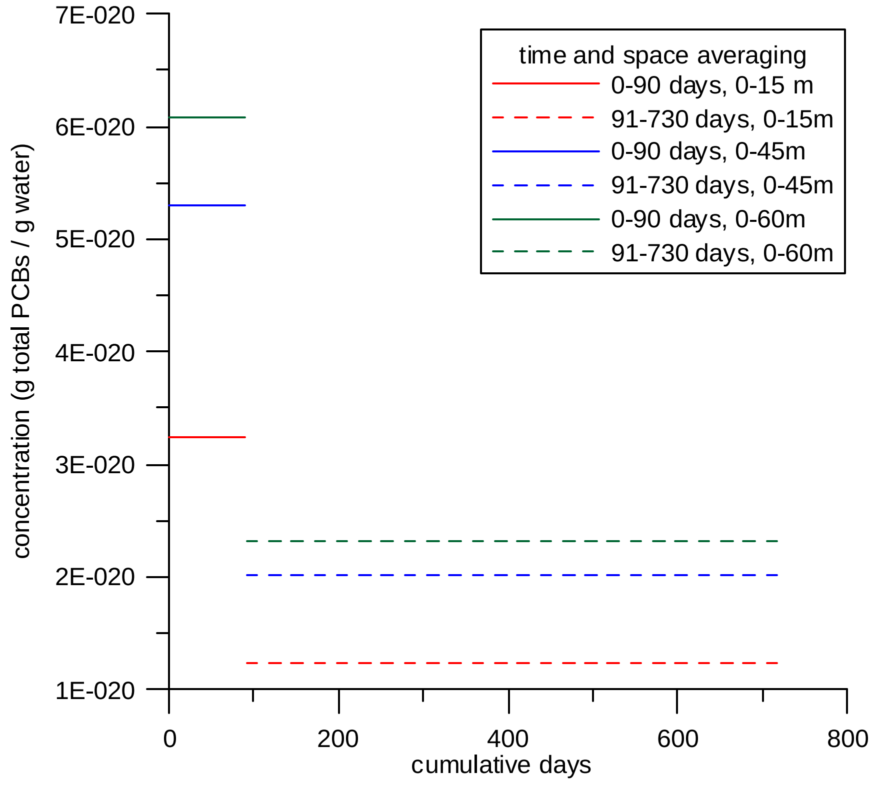


Figure G 2 – Average Total PCBs in TSS above pycnocline around Ship

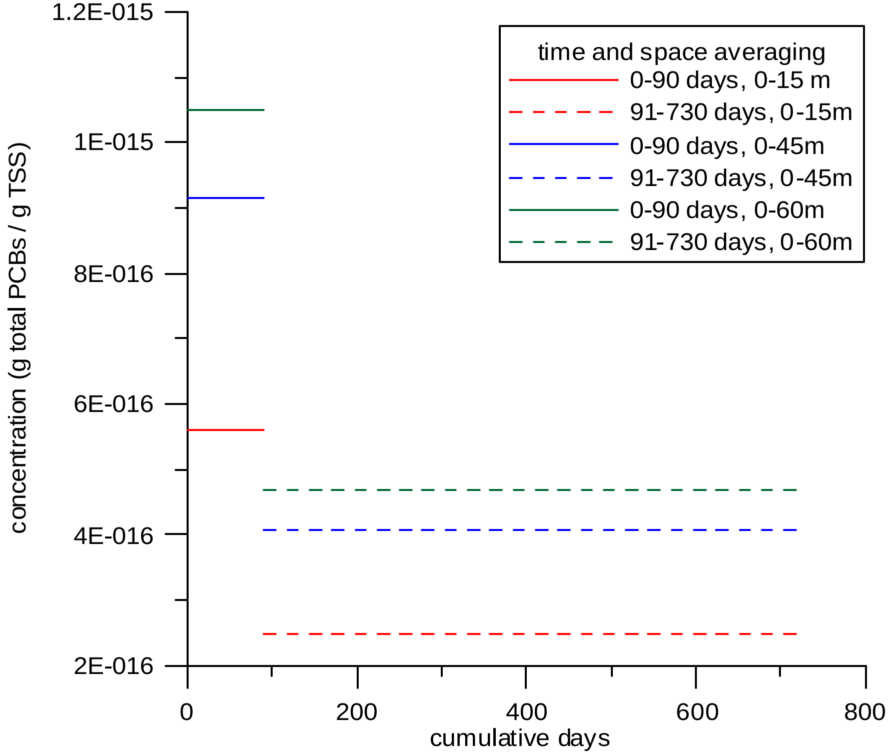


Figure G 3 – Average Total PCBs in DOC above Pycnocline around Ship

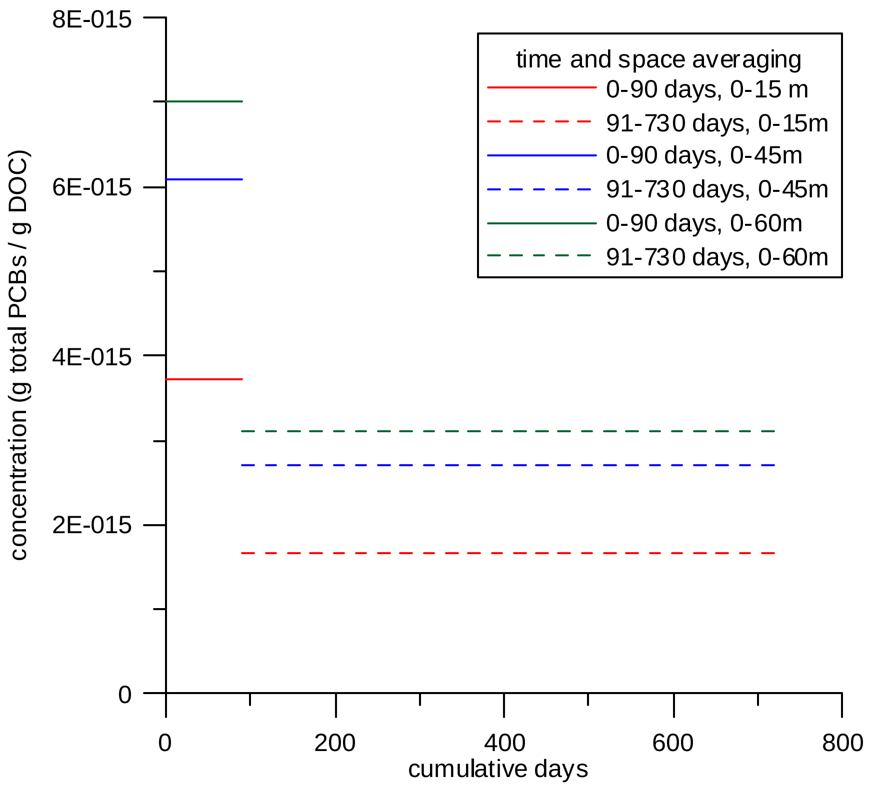


Figure G 4 – Average Total PCBs in Water below Pycnocline around Ship

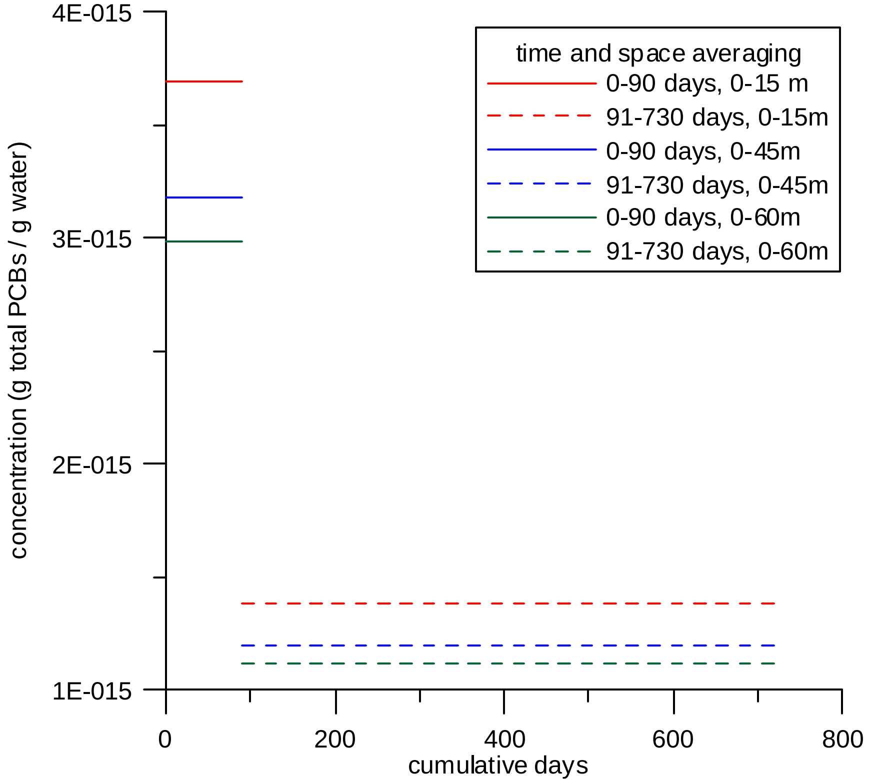


Figure G 5 - Average Total PCBs in TSS below Pycnocline around Ship

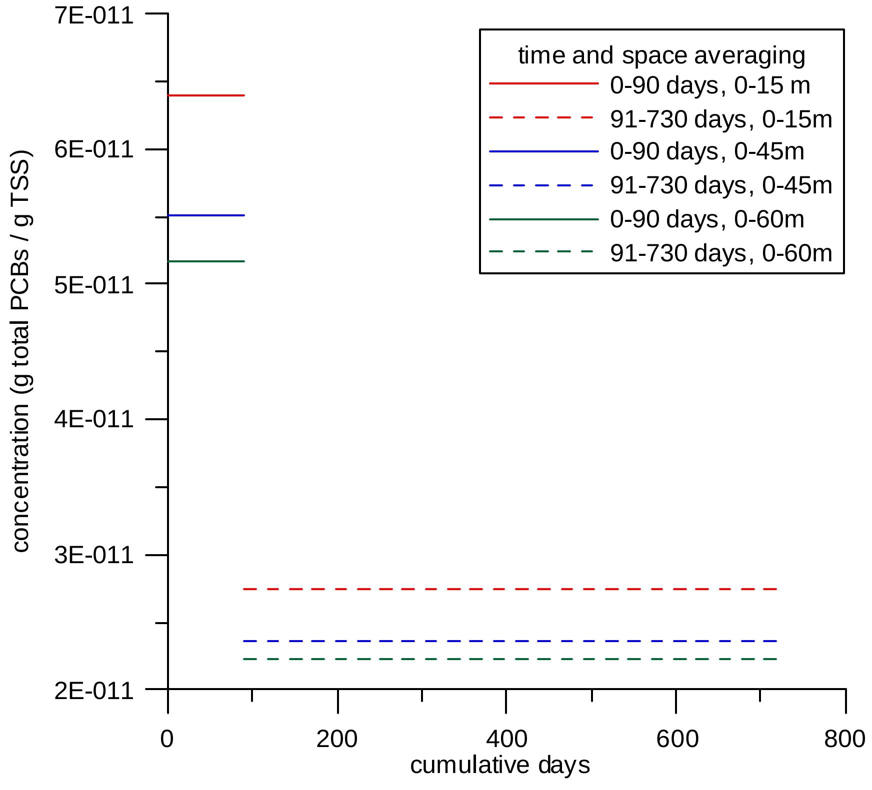


Figure G 6 - Average Total PCBs in DOC below Pycnocline around Ship

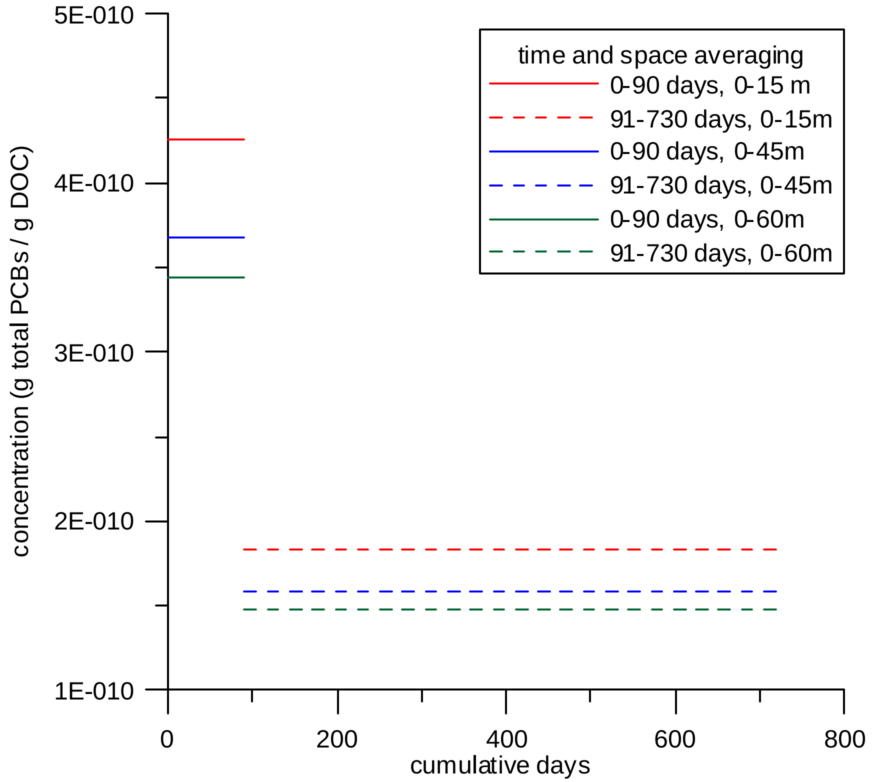


Figure G 7 – Average Total PCBs in Sediment around Ship

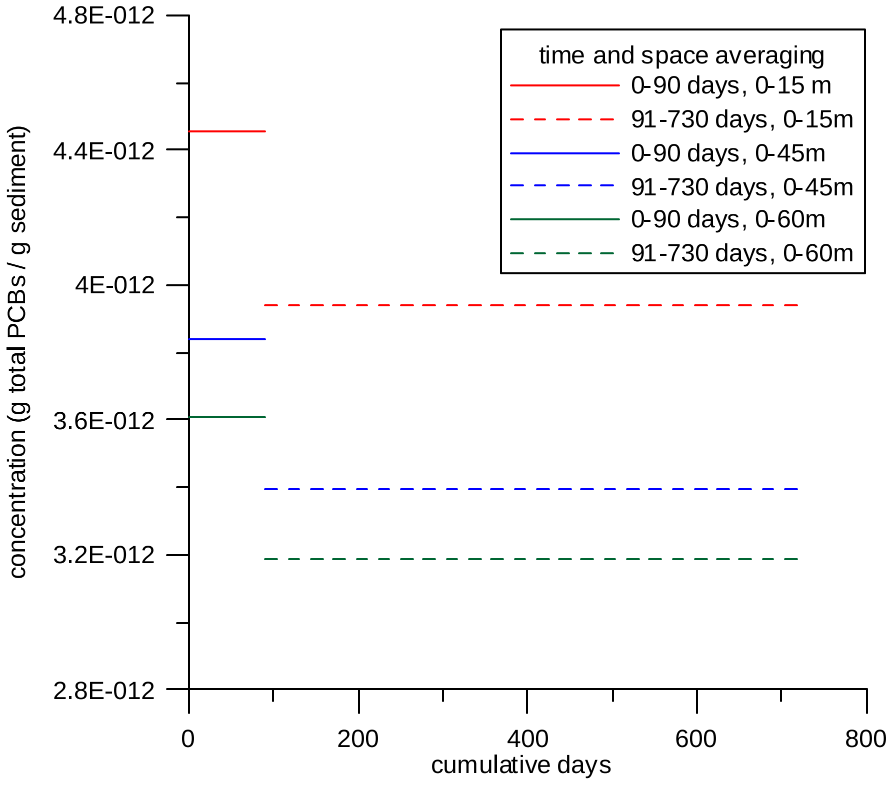
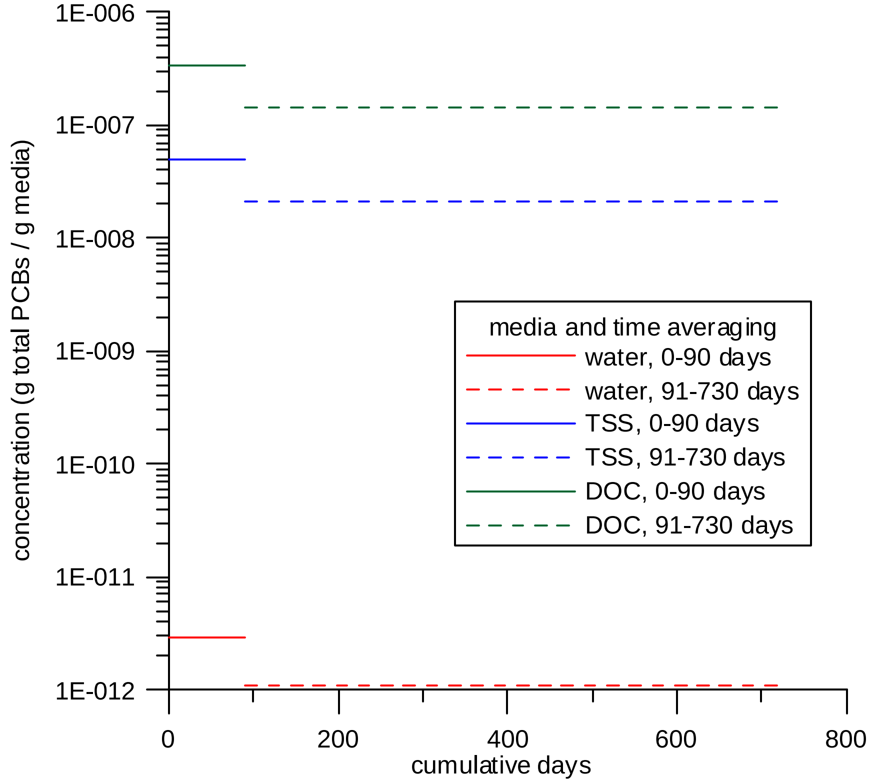


Figure G 8 – Average Total PCBs in Water, TSS and DOC inside Ship



Distance 0-15 meters from reef

		Total PCB Concentration (mg/kg-ww)							
		1 day	1 week	2 weeks	1 month	6 months	1 year	2 years	Weighted average for all time intervals
Time Interval Duration (days) =		1	6	7	14	152	185	364	
Cumulative Time Elapsed (days) =		1	7	14	28	180	365	729	
Pelagic Community									
Phytoplankton (TL1)	Algae	3.12765E-11	4.16492E-11	5.35389E-11	5.82831E-11	4.65747E-11	2.14354E-11	1.46835E-11	2.45015E-11
Zooplankton (TL-II)	copepods	4.944E-05	5.75065E-05	7.2603E-05	6.76289E-05	5.33509E-05	2.34653E-05	1.82086E-05	2.87076E-05
Planktivore (TL-III)	herring	0.000236408	0.00027377	0.000373418	0.000373723	0.000311734	0.000132158	8.95083E-05	0.000156569
Piscivore (TL-IV)	jack	0.000302821	0.000341794	0.000485316	0.000527592	0.00048126	0.000192956	0.000135292	0.000234886
Reef / Vessel Community									
Attached Algae	Algae	4.41045E-06	5.16875E-06	6.63623E-06	6.41618E-06	5.21289E-06	2.24012E-06	1.72965E-06	2.75456E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	0.000103701	0.000121316	0.000153023	0.000141784	0.000110466	4.89206E-05	3.76943E-05	5.96018E-05
Invertibrate Omnivore (TL-II)	urchin	0.021178532	0.024845691	0.033714051	0.033247415	0.026999337	0.011629279	0.00774156	0.013641918
Invertibrate Forager (TL-III)	crab	0.018701646	0.024901928	0.037543352	0.045500424	0.044448692	0.022055467	0.016613838	0.024625271
Vertibrate Forager (TL-III)	triggerfish	0.014528923	0.016958752	0.023689593	0.031953844	0.05677715	0.030363737	0.030144268	0.035595877
Predator (TL-IV)	grouper	0.013512442	0.015698419	0.022256708	0.023685826	0.048425837	0.035217167	0.051486848	0.045558597
Benthic Community									
Infaunal invert. (TL-II)	polychaete	3.60617E-05	4.22179E-05	5.37109E-05	5.01287E-05	3.92287E-05	1.74317E-05	1.31892E-05	2.1064E-05
Epifaunal invert. (TL-II)	nematode	0.000100408	0.00011743	0.000152399	0.000144263	0.000114003	5.02702E-05	3.63521E-05	6.00166E-05
Forager (TL-III)	lobster	0.000229136	0.000268157	0.000361235	0.0003542	0.000287287	0.000124354	8.41686E-05	0.000146277
Predator (TL-IV)	flounder	0.000722275	0.000843806	0.001196268	0.001253345	0.001075737	0.000448812	0.000291896	0.000527432

Marine Finfish Ingestion Rates (from Table 10-52, 1997 Exposure Factors Handbook)			
	Mean	95th UCL	
	(kg/day)	(kg/day)	
North Atlantic	0.0062	0.0201	(ME, NH, MA, RI, CT)
Mid-Atlantic	0.0063	0.0189	(NY, NJ, MD, DE, VA)
South Atlantic	0.0047	0.0159	(NC, SC, GA, FL)
All Atlantic	0.0056	0.018	
Gulf Coast	0.0072	0.0261	(AL, MS, LA, FL)
Southern California	0.002	0.0055	
Northern California	0.002	0.0057	
Oregon	0.0022	0.0089	
All Pacific	0.002	0.0068	

Selected Igestion Rates
Gulf Coast

Fractional Ingestion Term			
RME	0.17	CTE	0.25

Adult to Child IR Scaling factor
0.356

Human Health Exposure and Effects Assumptions	Adult RME	Adult CTE	Child RME	Child CTE
Body weight (BW) (kg)	70	70	15	15
EF = exposure frequency for PCBs (days/year)	365	365	365	365
ED = reasonable maximum exposure duration for PCBs (years)	2	2	2	2
IR = fish/shellfish ingestion rate (kg/day)	0.0261	0.0072	0.0092916	0.0025632
ATc = averaging time for carcinogenic PCBs (days)	25550	25550	25550	25550
ATnc = averaging time for PCBs (days)	730	730	730	730
SF = slope factor for carcinogenic PCBs (mg/kg/day)-1	2	1	2	1
RfD = oral reference dose for noncarcinogenic PCBs (mg/kg-day)	0.00005	0.00005	0.00005	0.00005
FI = Fractional Ingestion (unitless)	0.17	0.25	0.17	0.25

RISK ESTIMATES	Total	Cancer Risk - Adult		Hazard Quotient - Adult		Cancer Risk -Child		Hazard Quotient - Child	
	PCB (ppm)	RME	CTE	RME	CTE	RME	CTE	RME	CTE
Benthic fish (flounder)	0.000527432	1.91E-09	3.88E-10	0.000668634	0.000271251	3.17E-09	6.44E-10	0.001110823	0.000450638
Benthic shellfish (lobster)	0.000146277	5.30E-10	1.07E-10	0.000185438	7.52283E-05	8.80E-10	1.79E-10	0.000308074	0.000124979
Pelagic fish (jack)	0.000234886	8.51E-10	1.73E-10	0.000297768	0.000120799	1.41E-09	2.87E-10	0.000494692	0.000200687
Reef fish TL-IV (grouper)	0.045558597	1.65E-07	3.35E-08	0.057755284	0.023430136	2.74E-07	5.56E-08	0.095950779	0.038925265
Reef fish TL-III (triggerfish)	0.035595877	1.29E-07	2.62E-08	0.045125401	0.018306451	2.14E-07	4.34E-08	0.074968333	0.030413117
Reef shellfish (crab)	0.024625271	8.92E-08	1.81E-08	0.031217807	0.012664425	1.48E-07	3.01E-08	0.051863184	0.021039831

Figure H-2

Distance 0-45 meters from reef

		Total PCB Concentration (mg/kg-ww)							
		1 day	1 week	2 weeks	1 month	6 months	1 year	2 years	Weighted average for all time intervals
Time Interval Duration (days) =		1	6	7	14	152	185	364	
Cumulative Time Elapsed (days) =		1	7	14	28	180	365	729	
Pelagic Community									
Phytoplankton (TL1)	Algae	5.11607E-11	6.81447E-11	8.75991E-11	9.53647E-11	7.62074E-11	3.50736E-11	2.40258E-11	4.00904E-11
Zooplankton (TL-II)	copepods	4.25981E-05	4.95647E-05	6.25764E-05	5.82924E-05	4.59856E-05	2.02259E-05	1.56948E-05	2.47444E-05
Planktivore (TL-III)	herring	0.00020368	0.000235958	0.000321844	0.000322129	0.000268699	0.000113914	7.71515E-05	0.000134954
Piscivore (TL-IV)	jack	0.000260864	0.000294579	0.000418275	0.000454755	0.000414822	0.00016632	0.000116615	0.000202459
Reef / Vessel Community									
Attached Algae	Algae	3.8E-06	4.45485E-06	5.71962E-06	5.5303E-06	4.49316E-06	1.93084E-06	1.49084E-06	2.37424E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	8.93507E-05	0.000104561	0.000131889	0.000122209	9.52153E-05	4.21666E-05	3.24902E-05	5.13729E-05
Invertibrate Omnivore (TL-II)	urchin	0.021136152	0.024796244	0.033645888	0.033178661	0.026942171	0.011605055	0.007725554	0.01361342
Invertibrate Forager (TL-III)	crab	0.018674696	0.024865059	0.037483853	0.045422253	0.044369814	0.022016885	0.016584826	0.024582134
Vertibrate Forager (TL-III)	triggerfish	0.014432638	0.016846963	0.023531567	0.031785562	0.056612132	0.030287264	0.03008096	0.035504651
Predator (TL-IV)	grouper	0.013433381	0.015606981	0.022126013	0.023545907	0.048265729	0.035122781	0.051380094	0.045443154
Benthic Community									
Infaunal invert. (TL-II)	polychaete	3.10714E-05	3.63872E-05	4.62929E-05	4.32078E-05	3.38128E-05	1.50251E-05	1.13683E-05	1.81558E-05
Epifaunal invert. (TL-II)	nematode	8.65128E-05	0.000101211	0.000131351	0.000124346	9.82637E-05	4.33299E-05	3.13332E-05	5.17304E-05
Forager (TL-III)	lobster	0.00019742	0.00023112	0.000311342	0.000305298	0.000247623	0.000107186	7.25479E-05	0.000126081
Predator (TL-IV)	flounder	0.000622262	0.000727248	0.00103102	0.0010803	0.000927218	0.000386848	0.000251595	0.000454611

Marine Finfish Ingestion Rates (from Table 10-52, 1997 Exposure Factors Handbook)			
	Mean	95th UCL	
	(kg/day)	(kg/day)	
North Atlantic	0.0062	0.0201	(ME, NH, MA, RI, CT)
Mid-Atlantic	0.0063	0.0189	(NY, NJ, MD, DE, VA)
South Atlantic	0.0047	0.0159	(NC, SC, GA, FL)
All Atlantic	0.0056	0.018	
Gulf Coast	0.0072	0.0261	(AL, MS, LA, FL)
Southern California	0.002	0.0055	
Northern California	0.002	0.0057	
Oregon	0.0022	0.0089	
All Pacific	0.002	0.0068	

Selected Igestion Rates
Gulf Coast

Fractional Ingestion Term			
RME	0.17	CTE	0.25

Adult to Child IR Scaling factor
0.356

Human Health Exposure and Effects Assumptions	Adult RME	Adult CTE	Child RME	Child CTE
Body weight (BW) (kg)	70	70	15	15
EF = exposure frequency for PCBs (days/year)	365	365	365	365
ED = reasonable maximum exposure duration for PCBs (years)	2	2	2	2
IR = fish/shellfish ingestion rate (kg/day)	0.0261	0.0072	0.0092916	0.0025632
ATc = averaging time for carcinogenic PCBs (days)	25550	25550	25550	25550
ATnc = averaging time for PCBs (days)	730	730	730	730
SF = slope factor for carcinogenic PCBs (mg/kg/day)-1	2	1	2	1
RfD = oral reference dose for noncarcinogenic PCBs (mg/kg-day)	0.00005	0.00005	0.00005	0.00005
FI = Fractional Ingestion (unitless)	0.17	0.25	0.17	0.25

RISK ESTIMATES	Total PCB (ppm)	Cancer Risk - Adult RME	Cancer Risk - Adult CTE	Hazard Quotient - Adult RME	Hazard Quotient - Adult CTE	Cancer Risk -Child RME	Cancer Risk -Child CTE	Hazard Quotient - Child RME	Hazard Quotient - Child CTE
Benthic fish (flounder)	0.000454611	1.65E-09	3.34E-10	0.000576317	0.0002338	2.74E-09	5.55E-10	0.000957455	0.00038842
Benthic shellfish (lobster)	0.000126081	4.57E-10	9.26E-11	0.000159835	6.48418E-05	7.59E-10	1.54E-10	0.000265539	0.000107724
Pelagic fish (jack)	0.000202459	7.33E-10	1.49E-10	0.00025666	0.000104122	1.22E-09	2.47E-10	0.000426399	0.000172981
Reef fish TL-IV (grouper)	0.045443154	1.65E-07	3.34E-08	0.057608936	0.023370765	2.73E-07	5.55E-08	0.095707646	0.038826631
Reef fish TL-III (triggerfish)	0.035504651	1.29E-07	2.61E-08	0.045009753	0.018259535	2.14E-07	4.33E-08	0.074776203	0.030335174
Reef shellfish (crab)	0.024582134	8.90E-08	1.81E-08	0.031163123	0.01264224	1.48E-07	3.00E-08	0.051772334	0.021002975

Figure H-3

Distance 0-60 meters from reef

		Total PCB Concentration (mg/kg-ww)							
		1 day	1 week	2 weeks	1 month	6 months	1 year	2 years	Weighted average for all time intervals
Time Interval Duration (days) =		1	6	7	14	152	185	364	
Cumulative Time Elapsed (days) =		1	7	14	28	180	365	729	
Pelagic Community									
Phytoplankton (TL1)	Algae	5.87324E-11	7.82394E-11	1.00576E-10	1.09494E-10	8.74987E-11	4.02704E-11	2.75856E-11	4.60303E-11
Zooplankton (TL-II)	copepods	3.9991E-05	4.65385E-05	5.87558E-05	5.47348E-05	4.31792E-05	1.89915E-05	1.4737E-05	2.32342E-05
Planktivore (TL-III)	herring	0.000191209	0.00022155	0.000302191	0.000302469	0.000252301	0.000106962	7.2443E-05	0.000126718
Piscivore (TL-IV)	jack	0.000244876	0.000276587	0.000392729	0.000427001	0.000389506	0.00015617	0.000109498	0.000190103
Reef / Vessel Community									
Attached Algae	Algae	3.56739E-06	4.18282E-06	5.37035E-06	5.19275E-06	4.21892E-06	1.81299E-06	1.39985E-06	2.22933E-06
Sessile filter feeder (TL-II)	bivalves (w/o shell)	8.38827E-05	9.81769E-05	0.000123836	0.00011475	8.94039E-05	3.9593E-05	3.05071E-05	4.82373E-05
Invertibrate Omnivore (TL-II)	urchin	0.021120004	0.024777403	0.033619915	0.033152463	0.026920388	0.011595824	0.007719456	0.013602561
Invertibrate Forager (TL-III)	crab	0.018664428	0.024851011	0.037461181	0.045392467	0.044339758	0.022002184	0.016573771	0.024565697
Vertibrate Forager (TL-III)	triggerfish	0.014395949	0.016804367	0.023471352	0.031721439	0.056549252	0.030258124	0.030056837	0.03546989
Predator (TL-IV)	grouper	0.013403255	0.015572138	0.022076213	0.023492592	0.048204721	0.035086815	0.051339417	0.045399166
Benthic Community									
Infaunal invert. (TL-II)	polychaete	2.91699E-05	3.41655E-05	4.34664E-05	4.05706E-05	3.1749E-05	1.4108E-05	1.06744E-05	1.70476E-05
Epifaunal invert. (TL-II)	nematode	8.12179E-05	9.50315E-05	0.000123331	0.000116756	9.22663E-05	4.06853E-05	2.94208E-05	4.8573E-05
Forager (TL-III)	lobster	0.000185335	0.000217007	0.00029233	0.000286664	0.00023251	0.000100644	6.81199E-05	0.000118386
Predator (TL-IV)	flounder	0.000584153	0.000682834	0.000968053	0.001014363	0.000870625	0.000363237	0.000236239	0.000426863

Marine Finfish Ingestion Rates (from Table 10-52, 1997 Exposure Factors Handbook)			
	Mean	95th UCL	
	(kg/day)	(kg/day)	
North Atlantic	0.0062	0.0201	(ME, NH, MA, RI, CT)
Mid-Atlantic	0.0063	0.0189	(NY, NJ, MD, DE, VA)
South Atlantic	0.0047	0.0159	(NC, SC, GA, FL)
All Atlantic	0.0056	0.018	
Gulf Coast	0.0072	0.0261	(AL, MS, LA, FL)
Southern California	0.002	0.0055	
Northern California	0.002	0.0057	
Oregon	0.0022	0.0089	
All Pacific	0.002	0.0068	

Selected Igestion Rates
Gulf Coast

Fractional Ingestion Term			
RME	0.17	CTE	0.25

Adult to Child IR Scaling factor
0.356

Human Health Exposure and Effects Assumptions	Adult RME	Adult CTE	Child RME	Child CTE
Body weight (BW) (kg)	70	70	15	15
EF = exposure frequency for PCBs (days/year)	365	365	365	365
ED = reasonable maximum exposure duration for PCBs (years)	2	2	2	2
IR = fish/shellfish ingestion rate (kg/day)	0.0261	0.0072	0.0092916	0.0025632
ATc = averaging time for carcinogenic PCBs (days)	25550	25550	25550	25550
ATnc = averaging time for PCBs (days)	730	730	730	730
SF = slope factor for carcinogenic PCBs (mg/kg/day)-1	2	1	2	1
RfD = oral reference dose for noncarcinogenic PCBs (mg/kg-day)	0.00005	0.00005	0.00005	0.00005
FI = Fractional Ingestion (unitless)	0.17	0.25	0.17	0.25

RISK ESTIMATES	Total	Cancer Risk - Adult		Hazard Quotient - Adult		Cancer Risk -Child		Hazard Quotient - Child	
	PCB (ppm)	RME	CTE	RME	CTE	RME	CTE	RME	CTE
Benthic fish (flounder)	0.000426863	1.55E-09	3.14E-10	0.000541141	0.00021953	2.57E-09	5.21E-10	0.000899015	0.000364712
Benthic shellfish (lobster)	0.000118386	4.29E-10	8.70E-11	0.000150079	6.08841E-05	7.12E-10	1.44E-10	0.000249332	0.000101149
Pelagic fish (jack)	0.000190103	6.89E-10	1.40E-10	0.000240997	9.77673E-05	1.14E-09	2.32E-10	0.000400376	0.000162424
Reef fish TL-IV (grouper)	0.045399166	1.64E-07	3.34E-08	0.057553171	0.023348142	2.73E-07	5.54E-08	0.095615002	0.038789047
Reef fish TL-III (triggerfish)	0.03546989	1.28E-07	2.61E-08	0.044965686	0.018241658	2.13E-07	4.33E-08	0.074702993	0.030305474
Reef shellfish (crab)	0.024565697	8.90E-08	1.80E-08	0.031142285	0.012633787	1.48E-07	3.00E-08	0.051737717	0.020988932